TRANSACTIONS

of the

American Fisheries Society

"To promote the cause of fish culture; to gather and diffuse information bearing upon its practical success, and upon all matters relating to the fisheries; to unite and encourage all interests of fish culture and the fisheries; and to treat all questions of a scientific and economic character regarding fish."

VOLUME XLVIII

1918-1919

Edited by Raymond C. Osburn

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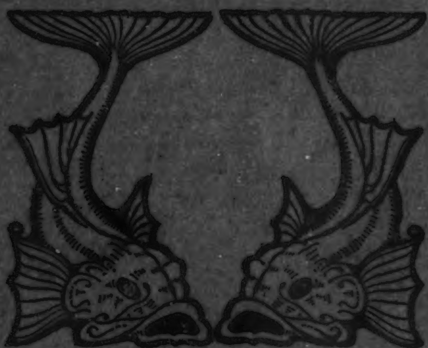
AMERICAN FISHERIES SOCIETY



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THE ELIMINATION OF STREAM POLLUTION IN NEW YORK STATE.

By Henry B. Ward,
University of Illinois.

Mr. President, and Gentlemen of the Society:

The importance of the problem of stream pollution may be judged from a recent statement by one of the members of the United States Food Administration, charged with responsibility for the fish foods and their distribution, who said that among all the suggestions which had been made from all the states of the Union with reference to the improvement of the fisheries and the increase in the product, more than sixty per cent of them dealt with stream pollution.

The situation is naturally worse in the seacoast states, in the older states and in the manufacturing states. It naturally is least significant in the parts of the country that lie at a distance from the ocean and removed from centers of manufacture. You will easily recognize that in the heart of the Adirondacks stream pollution is not a serious problem. Most of you who read the newspapers are aware of the fact that New York City regards stream pollution as a very important problem from the standpoint of the municipality and its activities, and no one connected with fish work who comes in contact with the Hudson will question that the yield of that stream and its value as an asset for the state and the nation are greatly reduced by the conditions that exist in the stream at the present time.

The importance of the question was such and my interest in the biological side of it, which I had studied incidentally for some time, was so great, that I accepted with pleasure the invitation from the Conservation Commission of New York State to spend the summer working with them to bring together the data, to organize them into a plan, and to see what steps might be practicable in attempting to reach a solution of the problem, a removal of the difficulty; and I want here to acknowledge publicly, if I may, the courtesies that I have received at the hands of the Commission. Every one of the gentlemen with whom I have

F. P.

come in contact has manifested the greatest sympathy and interest in the problem, and has gone out of his way to make me acquainted with facts, and to assist me in analyzing conditions and in formulating a plan for the change of these conditions.

We have been accustomed from the engineering and scientific standpoint to separate wastes into two types, speaking of domestic sewage on the one hand and industrial wastes on the other hand, domestic sewage consisting, briefly speaking, of waste discharges of an organic character; materials that are rapidly attacked under natural conditions, transformed into substances that serve as food for different kinds of organisms, and in the processes of nature are soon removed, or made over into useful substances; the industrial wastes on the other hand consisting of chemical materials, dyes and acids, and other substances entirely foreign to the water under natural conditions, substances which remain often unchanged for considerable periods of time; and their effects consequently are felt over a greater extent of the stream than in the earlier case. Further, their effects are very much more serious and are exerted often through the inflow of a smaller amount of material.

Now the classification is all right from a scientific and practical point of view, but it is all wrong from the facts in the case; and if you stop to think for the moment you will see what is meant. This I consider of fundamental importance in our discussion of the problem, because it has been customary in writings to set aside domestic sewage, to say that it was under the control of Boards of Health, that it was rapidly made over by processes of nature, that it stood on an entirely different footing from industrial wastes, and that probably it ought not to be considered in such a discussion as this.

The laws of New York State are drawn to distinguish between the two; very likely the laws of other States also; but if you think for a moment that even in the smallest town almost, there are little manufacturies here and there, that there is an occasional small mill or chemical shop, and that there is certainly a garage, or two, or three; these are places from which chemical wastes, acid wastes and oil wastes and other materials of that type are being poured into the city sewage system, into the canals, the sewers, and through these are reaching with the other material

the stream or water body into which the sewage is emptied. Now, take a large manufacturing city, and think for a moment how extensive those chemical wastes are that thus indirectly reach, with the sewage of the city, the stream with which we are immediately concerned.

The city of Troy, and I take that merely as an example, because you all know of its reputation as the great place of manufacture for collars and cuffs and shirts,—the city of Troy has enormous laundries. Washing fluids, coloring matter, chemical materials of powerful character are being discharged into the city sewage and are reaching the Hudson River through the sewers. They are no less significant than are the discharges from the paper mills located on the banks of the stream, that happen to be pouring a quantity of waste directly into the waters of the river, so that when we actually take up the analysis of the question it seems to me important that we should dismiss from our minds the somewhat artificial distinction between industrial wastes and domestic wastes, for that distinction no longer holds in practice, and the sewage wastes partake of the character of the chemical wastes and consequently, the kind of chemical being considered, produce the same sort of effect.

I hardly need to tell you that in recent times stream pollution has enormously increased. There are some features of the situation that all understand. The effect of waste is related rather directly to proportion between its amount and the flow of the stream, or the volume of the body of water which is disturbed. If you throw into Lake Erie a teacupful of prussic acid, which no one fails to recognize as a most violent poison, it might be difficult to detect the influence at once and surely a short time after the occurrence there would be no trace of the effect. Multiply the contamination by a hundred or a thousand and the effects become conspicuous. So it has been with stream pollution. When the land was young and the population scattered, anything could be done without serious results. Starting from that beginning, a small factory or a little mill on a stream, we have come to the point today where large mills and tremendous factories line the banks of the stream, and while the individual contribution seems to have but little effect, the total contribution is of very great influence. That has introduced into these situations an element

which must be kept in mind. At the start of our development the little factory was permitted to establish itself. It has acquired by virtue of that permission, a certain sort of a right. If at the present day we were to introduce a law, or enforce a law in such measure as to stop all industry, we should do ourselves, the cause we advocate, and the end for which we are striving with all our might, incalculable harm. I think that no fair-minded man really looks for a solution of the question which would endeavor to introduce and enforce on the moment a radical policy of suppression.

Having considered these general questions, let us pass for a moment to an examination of the situation as it exists, and I take care in this case not to go into it at all exhaustively, but to note a few facts that have come out of my work here in the State of New York. The same thing applies in large degree, if not throughout, to other states of the Union. The mere start on the problem opened up naturally some of the reports on file in the office of the Conservation Commissioner; and it was found that a considerable number of places had been reported because the results of stream pollution were so extreme as to force themselves upon the attention of state officials, and that here a small mill had been prosecuted and fined for pouring waste into a stream that wiped out all life of that stream and there an oil refinery had been handled in somewhat similar fashion. At another point a group of tanneries had been brought under pressure, had introduced a plan for the handling of the waste and had ameliorated the condition, if not entirely corrected it.

Following upon the discovery of these reports a questionnaire was sent out to every one of the game protectors in the state. Now the New York State Conservation Commission is fortunate in having a considerable force of these splendid employees devoting their time to a study of natural conditions. The game protectors received and replied to the questionnaire without any suggestion as to the reason for its being sent them. It was, in other words, to them one of the many inquiries that every official receives in the form of a questionnaire which he has to answer and return to the main office; and up to that time there had been no outside discussion of any special consideration of the problem of protection or of stream pollution in general. I

have here a summary of those questions and answers. It seems to me that they are very significant. We must keep in mind the fact that these are not men of technical training, either in chemistry, biology or in manufacturing. They are men of the woods; they are men accustomed to use their eyes, men of reasonable judgment in interpreting things they see, but not trained to deduce scientific conclusions from them, or to get precise and accurate measures of conditions. In the hundred replies it is very easy,—for there were just one hundred and one replies,—to see what the percentage was from the definite answers to the questions.

On the first question, asked if the individual had personal knowledge of specific instances where the discharge of wastes into streams was injurious to fish life, fifty-two of them gave an unqualified affirmative reply.

With regard to the second question, one-third of them, thirty-five, said that the effects varied from time to time. There were forty of them who were able to cite other persons able and willing to give further evidence of the existence of such specific pollution, injurious to fish life. I will not go into detail, but will mention only a few of the more significant cases. Twenty of them knew of instances and cited them where the property holders along the streams had suffered damage to live stock or property through the discharge of wastes into the waters, so that the effect was not confined to the effect in the water itself but extended even on to the land. Then there were seventy of them who said that they had not observed any change benefitting or injuring the fish after handling the waste, that is, after treatment of the wastes in various ways, but thirty of them had noticed specifically that the treatment of wastes at certain points had resulted in benefiting the fish life in the stream. Forty-nine of them, almost half, were positively of the opinion that the wastes from industrial plants in their observations affected the streams more seriously than the wastes in the city sewage; and in the classification of effects, thirteen of them cite milk plants in general, that is, canneries and factories and all the various plants that have to do with the handling of milk and its products. Eight cited oil and tar plants; thirty-five, works using acids; twenty-three, works using various chemicals; twelve, dye-stuffs; ten, tanning factories;

six, gas plants separately; nine, sulphite paper mills, and eleven, canneries. There were also some specific suggestions made by thirty of them with regard to methods by which the problem might be investigated or places at which it could profitably receive attention.

Under the advice of the Commissioner, I took occasion to visit a series of typical locations in the state, to see the effect of a group of manufacturers of the same type, and the localities selected included tanneries, sulphite paper mills and mills using or producing chemicals.

Now the natural objection to the demonstration of the existance of such wastes, and the seriousness of their effects, which was supported by a mass of testimony,—the natural objection to this is that it constitutes an unfortunate but a necessary and inevitable accompaniment of the development of manufacturing. But such a general argument as that is readily and perfectly met when we consider for a moment the conditions that prevail in other countries. When the manufacturer makes a statement to you or to any other person, and you ask him if manufacturing is as general, if population is as dense, in this country as it is in England or Belgium or France or Germany, taking conditions before the war, he will hardly venture to say that it is. We have in none of our states reached the development of manufacturing, we have in none of these states reached the density of population which exists in those countries. And yet fishing in the streams of the old world is better than it is in these streams in the manufacturing parts of the new world; and pollution at the present time is much greater here than it is there. Much improvement, as a matter of fact, has been made in the older parts of the world in the course of the last half century in cleaning up the streams, for they have paid attention to that, whereas of course we have rather neglected the problem.

In order to attack the difficulty properly it is necessary for us to consider the essential factors which are concerned in it. The situation is complex and not readily seen. If we go out to study conditions on the land, we see them with our own eyes. As we look at water its surface mirrors the beauty of the surroundings, but hides some of the conditions beneath, and it requires a very marked change in the character of the stream and the life

in it to bring about such conditions that they appeal to us, to our eyes, as departing from natural conditions, and as affording limitations or restrictions upon the development of aquatic life; but the essentials of existence under the water are the same as those which prevail on the land. A land animal requiring oxygen, must be able to breathe. It requires food. You shut it off from a supply of fresh oxygen, and it dies. You eliminate the food, and the animals are driven away or perish. Precisely the same conditions prevail under the surface of the water. If any factors reduce beyond a reasonable limit the supply of oxygen, the organisms that live in the water will be smothered. If any conditions drive away or destroy the food, the animals which depend upon that food will migrate or starve to death.

Let us apply this to the streams. It has been rather the fashion to test the effect of pollution on streams by looking for the fish, and if a fish was seen in the water, to say that that water was all right. It has been, in other words, the habit to rely upon a single criterion for judgment as to the quality of the environment. Most of you have seen areas here and there devastated by forest fires, and should anyone attempt to say to you that such an area was not damaged because he saw a deer run across it or a bird fly up and into it or out of it, you would smile at the crudity of such a suggestion. The same thing, however, applies perfectly well to fish. The fish are the largest and most powerful, and many of them are the freest in movement of all the water organisms. They course up and down streams. They make casual movements and migrations that cover considerable territory under varying conditions. They go about in search of food. When one area is crowded, pushing themselves off into other parts of the stream and seeking more favorable conditions for existence, they spread from point to point; and it is only rarely that one finds a stream in such a condition that the fish will not venture to enter into the water.

I can cite to you one instance which shows full well the significance of the argument that I am trying to bring before you at the present moment. The situation in Illinois is well known over the country in general. The city of Chicago has built a drainage canal which carries the city sewage down and into the Illinois and Mississippi rivers. The city of St. Louis at one time

carried out an action against the State of Illinois for polluting the waters on which St. Louis was dependent; and the conditions of the drainage canal, of the Illinois water and of all the water from Chicago down stream have been very carefully investigated. Now if you obsefve the river just below the point at which the drainage canal has emptied into it you will convince yourself very readily that it is nothing more in summer time at least, when the flow is reduced to nearly the lowest terms—it is nothing more than an open sewer, a septic tank in which the sewage has been deposited and in which changes are taking place to make over that organic material into a form such as can be utilized by the higher organisms. The little streams that run in are different in character. I have known of, and have seen, numerous instances where, watching such a little stream at the point of entering into the larger, one could see fish come down stream, swim up to what you would fix in your mind as the arbitrary line of division between the relatively pure waters of the small stream and the highly polluted waters of the main river; the carp would come to that line, stick their noses over it and go back again; come up again and do the same thing. They were possessed with a desire to migrate, but that desire was overcome by the conditions that they faced when they started to move from the smaller water into the larger. It is only very rarely one can see anything of that kind, because these larger fish often will pass into and through the highly polluted water in the endeavor to seek other regions where food is more abundant, or where for some other reason they desire to make their home.

Now then, the mere presence or movement of fish in any water is not necessarily indicative of the quality of that water. The second thing, of course, to which your attention must be called, is that different kinds of fish are very different in their susceptibility to impure water. From recently published experiments and tables it may be seen that the bullhead, for example, has a power of resistance or an indifference to polluted conditions which as compared to a minnow will be as forty-five to one,—so great is the difference between those two kinds of fish. Most of our valuable fish are rather sensitive to conditions of pollution, and do not find themselves happy or well situated in waters that are polluted to any extent, while some other fish can exist apparently without being incommoded.

But now as to a new test; the right measure of the condition of a piece of water is to be determined not by experimenting with that water on fish, but by observing the sum total of the living conditions in the water, and those living conditions may be determined by the examination and enumeration of the organisms that are to be found there.

Before I come to that, however, I want to say a word about one other thing. If you note these people who are arguing as to the harmless character of ordinary conditions in the streams, you will find that they very frequently say: "We know that fish are not very abundant there, and over-catching is the real reason for the diminution in the fish population of the individual stream." Now that sounds very true, and such a man will make a splendid argument as to the increase in the number of fishermen, the increase in the fondness for fishing and the increase in the means of getting about that has placed waters which formerly could hardly be reached in a week's vacation now almost within reach of a day's fishing trip. His conclusion is unassailable; the fish have been caught off. But, gentlemen, nobody has been catching the other organisms in the water; nobody has gone after insect larvae, or if they have been catching dobson or helgramites or something else for bait, they have not been catching the crustacea or the microscopic organisms of the water. If you take a pure stream and examine it under natural conditions, you will find it includes a rich and varied life; this is a fact with which you are perfectly familiar. There are green plants growing on stones; there are minute green plants floating in the water; there are little worms in the water; and other minute organisms of various kinds; if you take a net of bolting cloth you can collect a very considerable amount of that very stuff in all but in the most swiftly flowing streams. It is hardly necessary to state that that material which we speak of as plankton, constitutes the fundamental fish food of the water.

Now what about the food question? If the food is driven away from the water, if food is killed off, the fish will disappear; they will either be driven away or be starved out, and there is no possible alternative in the situation. Hence the simplest test in the world is to examine the waters so as to determine the existence of all those organisms that are characteristic of pure

free water. It gives an unanswerable argument, incontrovertible evidence in establishing the pollution of the stream; you have evidence not only that the existence of fish has been interfered with, but that if the fish were restored to the stream they would not find at the present time proper conditions for their existence there.

Now at various points in the country we are raising very considerable quantities of young fish. Those fish represent money. Each can of fry or fingerlings is a definite sum that the people of the state or the nation have put into this means for the replenishment of the water. And of what value is it, gentlemen, to pour fish into the stream where an examination of the conditions reveals the impossibility for the continued existence of such organisms.

I have hardly any need to remind you that it is the young fish which are of all most sensitive. All people have experimentally tried at times to make use of that sensitiveness as a measure of pollution. They have taken small or young fish and used them as tests of the purity of the stream. I want to try to show you the rather superficial character,—if you will permit me, with apologies, to designate it in that way,—of such a test by translating it into human terms, for this question is exactly the same problem that has concerned medical men and sanitary experts in seeking to control the condition of the air in manufacturing plants. Suppose a manufacturing plant were cited by a sanitary official for polluting the atmosphere and endangering the health of the workmen, and the expert should take a dozen children and divide them into two groups; six of them permitted to play in the air outside; and six were set on the floor of the manufacturing establishment for three hours or five hours. If they died the conditions were to be declared such as to demonstrate pollution of the atmosphere, and I do not suppose anyone would doubt that; but, gentlemen, the conditions with which we really have to deal are never so extreme as that. I would challenge you to cite a case of atmospheric pollution that would kill off even sensitive children within three or four hours. And yet that is what the same people expect the minnow test to do, to decide between what is right and not right. Of course if the minnows are killed, conditions are bad enough to demand instan-

taneous action on the part of somebody, but if they are not killed off, the situation has by no means been analyzed to the extent that is demanded. We must find out not merely whether short exposure to those adverse conditions is going to affect the fish unfavorably, but whether the conditions in the water have been so modified that the chance of the fish obtaining food, the chance of spawning and propagating itself, have been seriously interfered with.

And that brings us to a point where we should consider for a moment the different ways in which pollution affects fish life. I will pass over these very rapidly. Perhaps I should say the different ways in which fish affect the human species, for, after all, that is the fundamental point in our discussion and I need not say anything to you about the esthetic side of the question, fond as I know some of you to be of outdoor life. It will be suggested to you at once, that the people possess in our streams and ponds an asset for enjoyment that is of great value, and that should be preserved reasonably in its natural condition. I need not say anything to you as to the value of streams for the use of communities for bathing. No boy who is born, as I was, on the banks of the Hudson, brought up at a time when stream pollution had not reached its present condition, could fail to appreciate the value of going swimming. But some spots where I used to go swimming in the Hudson are to-day in such condition that anyone might well hesitate before he plunged into the water.

I want to speak definitely of the points at which we have suffered distinct financial loss. The pollution of our streams in the first place has been of definite financial damage to the landholder. He is unable to use the water for watering stock. He finds his cattle are poisoned in extreme instances, or do not thrive. He finds that his rights are interfered with, and of course that constitutes a legal right of action which to be sure is not often availed of because of the well known uncertainties of the law and of the difficulties which the individual meets in enforcing his rights against the larger and more influential body.

Then of course the greatest loss to the people is the loss in fish. Now I think pollution affects the adult fish, but it affects still more the young and the spawning grounds. Over the spawning grounds in a polluted stream is spread a mass of filth that

decays slowly. Those areas are not in condition to permit of spawning and proper development of the eggs. You would not expect that if you allowed such materials to fall down even in small quantities over the eggs in hatchery troughs you would make anything like a good report of your hatching operations. The young fish are very sensitive to these conditions, and I do not doubt that the reduction in the shad output of the Hudson River has been most radically affected at these two points in the life of the fish through the destruction of the spawning grounds, that is by the covering of the spawning grounds with decaying material, and through the pollution of the waters to such an extent that the young fish can not find proper conditions for existence.

I hardly need to mention that such conditions are slow in finding a recovery. A stream which has been visited with an acid bath, or scoured with a strong alkali, one in which all the life has been wiped out by a poison, such as prussic acid, takes many months, if not years, for its recovery, and it behooves us to establish such conditions that the initial destruction of life cannot take place.

A famous biologist who has studied carefully the waters of western Pennsylvania says that those streams where washings of coal have passed down them, are real deserts, barren of all kinds of life, and is inclined to the view that it will take centuries for their repopulation, if indeed ever it is possible to re-establish even approximately the conditions that existed there before.

Now it is a very conservative statement of the case to say that this destruction of natural resources does not fall under any reasonable construction, within the rights of the individual. I recall the time when people were accustomed to dump their garbage into vacant lots or back alleys, if not sometimes into front streets,—and I am not very old. Those conditions have been removed in certain parts of the country within relatively recent times, and I believe I am not far from right in saying that it might be possible to find places where such conditions prevail even at the present time. Those are precisely the conditions that exist in our waters. I have seen myself, as probably all of you have also and that within relatively recent times, on the passenger boats passing up and down our great rivers or along

the waters of one of the great lakes, cases where men brought great buckets of garbage to the edge of the boat and threw the stuff into the lake or the river, and where broken up boxes, together with the rinds of canteloupes or oranges were tossed overboard. I have seen places where that stuff floated to the shore. That is gross pollution of the water, and that sort of material lasts for some time. It is obnoxious to the eye. It offends us. But it is not stopped. Why? Because there seems to be in the minds of many people the idea that the waters are a sort of waste-basket, a garbage box, a dumping field, into which all kinds of waste can be thrown to get rid of it at any time.

Let us take a more serious thing. A tanker has come in from the ocean and entered one of our bays near here. Before reloading they have washed out the ship and have discharged into the water of the bay thousands of gallons of oil. I think that is not an exaggeration for the discharge is very large—they pump the mixed salt water and heavy oil refuse into the bay. It floats around on the surface in a scum so thick that if you push a row boat through it a line of the oil adheres as a distinct band to the side of the boat. It is not necessary to show in detail the certain effect on the aquatic life of that region. Surface organisms which form the food of many fish are totally destroyed and shore life suffers greatly also when the refuse is washed up on the beach.

All these things merely illustrate the indifference or ignorance of people generally with reference to the value of our water areas. In my opinion, the first thing needed in correcting the situation is a campaign of education. I do not believe that you will ever get the question of pollution settled until it is possible to teach the average man that these things are wrong, until the average man resents them in the same way you and I would resent our neighbors pitching garbage into the alley behind our homes or into the street in front of them. When public sentiment demands the correction of the situation, then it will be possible adequately to enforce the law.

But education must not concern itself merely with this phase of the problem which affects the people as a whole. Education must concern itself also with the individual responsibility for the wastes, with the manufacturer, with the person in control of

business interests, with the men at the head of affairs. Business is naturally conservative. It does not desire to move even if the movement is said to be advantageous, when the proposal has not been tried out by somebody else through a long enough period to establish the certainty that it will pay; and proper action will not be taken by manufacturers and by those who are responsible for the pollution until they are brought under the pressure of conscience and education as well as of law, until they have seen the public disadvantage and have learned something of the private advantage in handling the wastes instead of discharging them thoughtlessly into public waters.

Now the utilization of wastes is a rather complicated question. Most of you recall the way in which industrial commissions are forced to bring pressure on manufacturers to install safety devices. I think the majority of manufacturers, especially at the present time, will confess that it has been to their advantage to introduce such safeguards for labor, but it has required the force of a very powerful campaign with the public and in the halls of our legislatures to pass such legislation and to compel the introduction of protective devices in factories. The same thing is true right here. A concrete instance can be taken from New York State. The Standard Oil Company at Olean has a refinery which had discharged enough wastes at previous times to destroy all life in the stream into which they were emptied. Under the influence of the conservation law and of the pressure exerted for the enforcement of the law, they introduced a special plant for the refining and utilization of these waters. As a matter of fact that plant not only corrects the evil and protects the people, but it really yields to the company a good return on the investment. In other words, they were forced to undertake something which has proved to be for their financial advantage; but I doubt if there or elsewhere the same results would have been brought about unless it had been for the pressure exerted on them from the side of the people and of the Conservation Commission.

I shall pass over some other phases of the problem of education and speak for a moment of the need of investigation. These questions involve, of course, many very complicated problems. I have called your attention to the difficulties of deciding them in ways in which the problems of the past have been decided. I

do not believe it possible for the chemist to experiment with fish alone through a brief period, and establish the harmlessness of wastes. I think there has been an abundant amount of scientific investigation to show that many wastes are harmful in the worst possible sort of way, tho on short experimentation these substances seem to exercise no particular influence over the fish. To show you how insignificant, how very small an amount of a chemical may be when it operates at a long distance, let me cite to you a specific instance. The city of Lincoln, Nebraska, uses water for drinking purposes from deep wells. At one time there was typhoid fever in the city. It was suggested that in some way these wells had become contaminated, and the city started at once treating the water with chlorine in very small amounts. We had in the zoological laboratory a big aquarium room in which were kept a lot of cultures of microscopic organisms. That room was supplied with city water. It was at a distance of several miles from the point where the water was treated. We were unable by tests to determine the presence of chlorine in the water and yet these microscopic organisms promptly died off, and it was impossible to reestablish the cultures; they would not live in that water.

Now the food of the fish consists of or is dependent on those organisms. The small fish might eat them themselves. Larger fish would eat an intermediate sized organism that ate this smaller type. The destruction of that food would drive away any fish just as directly as if the fish themselves had been affected by it; and I am not here to contend that the fish are not affected by it, although the degree of influence on the fish was so small that it could not be told by the type of experimentation which has ordinarily been tried.

In the next place I want to call your attention to the fact of changes which are making very serious modifications of natural conditions, changes that are well-illustrated in New York state and also at many other points. We are beginning to make over natural water systems into a series of ponds. When we put up dams, in what was formerly a rippling stream coming down over the rocks, absorbing large quantities of oxygen, and undergoing changes that tend to purify it and put it in splendid condition, there is substituted for it a deep pond almost without movement

of the water; the stream is being utilized for power. The result of that can be seen very clearly when one examines such a place as the upper Hudson. The sulphide wastes from a mill at the upper end of the series of sulphide mills have accumulated in a basin behind a big power dam until this upper lake has a bottom covered with polluted material and without the evidences of life characteristic of clean and unpolluted water. Where the water comes over the dam—or through the wheels, as it mostly does—it shows evidence very clearly of its polluted character as it starts down over a long series of riffles below the dam. You can see in the lack of the organisms characteristic of free water and in the presence of organisms characterizing polluted water, that there is pollution in the water near the dam; if you follow the current down over the riffles the organisms of pollution gradually disappear, the organisms that are in free water gradually appear until you come to the next relatively still waters, of Big Bay as it is called, above Glens Falls, where you get a rich growth of green plants and all other conditions that indicate pure water. In that stretch of the river there is splendid fishing. It is in passing Glens Falls, Hudson Falls and Fort Edward, with their numerous sulphide mills, that the water accumulates its pollution again, and below Fort Edward it has just the character that was manifested in the polluted basin higher up, only in more conspicuous and extreme fashion. These conditions suggest to us what will happen when another dam is built, and one is projected near the foot of the riffles at the head of Big Bay. It will transform the riffles above the site of that dam into a pond. Within that pond the slower movement and the limited contact of the water with the atmosphere will prevent the acquisition of oxygen, will prevent correcting the conditions of pollution, and will transform that stretch of the river also into a polluted basin. And so the building of a series of dams may readily make over a stream from one which is able to purify itself, despite the waste added to it, into one in which such conditions for purification will not exist. It behooves us then to consider the pollution question not merely on the basis of present conditions, but on the basis of probable changes which will accentuate those conditions that are unfavorable.

Important as the question of pollution is from the standpoint of food for the war, we must not forget that its significance reaches much further into the future. Food will probably never be as cheap in the future as it has been in the past. If we are to have in this country those conditions of existence affording a varied food supply of an abundant type which has given the physical vigor, intellectual strength and independence that we as Americans are proud of, we must see to it that all possible means are taken to increase the food supply, to check these limitations on it, to improve the conditions that surround its production. We have in stream pollution, in my opinion, one of the most important of these factors. We have means of testing it definitely, and beyond question when those means are applied by a careful study of the situation and when the conditions that these tests reveal are made known to the people at large through campaigns of education. When the situation is brought home to men in positions of leadership, responsible for establishing these conditions, the pollution will be eliminated and the streams restored to something like their original purity. But, gentlemen, without the cooperation involved in that outline of conditions we shall not be able to correct the situation. So sure as we start upon the reform of these conditions with violence, with suddenness, or regardless of great industries that are essential for the prosperity of the country, just so soon shall we involve ourselves in discussion and contention in which, without public support, our cause will be lost.

DISCUSSION.

Mr. N. R. Buller, of Pennsylvania. Mr. President, the commonwealth which I represent has more pollution within its boundaries than any other state in the Union, on account of its vast mining interests and its industrial conditions. We have at present approximately 60,000 mines and industrial establishments within our borders. Only a few years ago, during the term of my predecessor, the first efforts to stop pollution were made. I believe with Dr. Ward, after the experiments that have been made, that the only true remedy is cooperation and education. Bringing prosecutions and imposing fines does not remedy the conditions.

Pennsylvania has made vigorous efforts to correct these evils. The functions are divided, the Department of Health having jurisdiction in so far as sewage of cities is concerned and the Department of Fisheries over industrial conditions and mines. I am of the opinion that this is wrong and that it should be under one head having authority over both sewage and industrial questions.

Pollution in Pennsylvania is at present increasing, due to the great activities of the war, and the Department of Fisheries is flooded with protests from all sections of the state concerning the destruction of fishes. The great munition plants have so increased their activities and capacity that on the west branch of the Susquehanna River from Emporium to Sunbury, a distance of about ninety miles, the discharge of the past six months has killed every living thing in the river, where heretofore there was reported good fishing. The Attorney General of the Commonwealth has advised that under present conditions no prosecutions shall be brought, but that investigations be made and data furnished the War Industries Board at Washington. This board has indicated to our Fisheries Department that they are investigating and that if it is possible to avoid this pollution it will be stopped.

Mr. Carlos Avery, of Minnesota. Dr. Ward has sounded the key note in saying that a campiagn of education is first absolutely necessary. We naturally apply what he says to our own localities and conditions. The Upper Mississippi has been for years and is yet one of the most famous breeding grounds for many varieties of food fishes. At the Twin Cities we have a population now approaching a million people using the Mississippi River as a sewer, and nobody has ever thought of anything different. All the way down the river we find the smaller cities doing the same thing. Now if that is going to result in the extermination, or in a serious depletion, of the fish life of the Mississippi River, we ought to begin to consider that problem. In connection with the educational program that Dr. Ward has suggested, it seems to me that we ought to go farther and be prepared with some suggestions as to remedies. I would like to ask him whether he could in the case of Minneapolis and St. Paul, suggest anything that would, in a measure, dispose of the sewage of those cities without polluting the Mississippi River.

Fishermen have told me that they have found solid wastes from the packing plants of South St. Paul forty and fifty miles below that point, grease, hair and other wastes that could be positively identified as coming that long distance, showing that it must affect the river for many miles. If Dr. Ward could supplement what he has already said by some suggestions along this line it would be very helpful to us in our locality.

Mr. M. L. Alexander, of Louisiana. The manner in which Dr. Ward has analyzed this situation has given us an entirely different view point on the question. We have been impressed too much in the past with the value of the industry located on the stream. We have lost sight of the fact that the streams and the life of the streams belong to the whole people, and therefore should be protected. I am thoroughly convinced of the fact, however, that it is going to take a campaign of education to bring about the desired results. I believe that this Society could not take up any greater work than this of educating the people throughout the United States to the necessity of eliminating stream pollution and of devising ways and means by which factories and other great industries located along the streams

throughout the United States may take care of their wastes. Some means must be adopted to remedy the condition and therefore this Society could well adopt as its slogan, "the reduction of stream pollution." I hope that this paper of Dr. Ward's will be published and spread broadcast throughout all the states of the Union.

Mr. George D. Pratt, of New York. This difficulty looks like an insurmountable one. All of the rivers of all of the states are being polluted. There is no question about it. In New York we have a law which prohibits the putting of pollution in streams where it is destructive to fish life. I do not agree with Mr. Buller that fines and penalties do not have a helpful effect. In New York they are very helpful and in our experience we have found that people who are fined for pollution immediately make an endeavor to improve the condition. Last week some of the people who had been polluting the streams, with representatives from Cornell University and the Commission met in Albany and went over this whole matter to see what we could do to form a policy.

One question that Dr. Ward brought up concerns the throwing of refuse from steamers. It would be a very simple matter to pass a law absolutely prohibiting steamers from throwing refuse into the water. They can consume it just as well as not in their furnaces.

In the case of pollution by manufacturers, we are trying to get the manufacturers in and to confer with them. There is a feeling on their part that they do not want to give away any of their secrets, but by a cooperative spirit on their part and on that of the Commission we may get them to tell each other how they can prevent pollution.

Now pollution can be prevented, and in New York we propose to go at it. It is not a question of doing it in a day. I believe if we all had laws passed as was done with the railroads in regard to air brakes, etc., and give these people five years to get rid of their pollution, and after that time, go after them hard, that it can be done. If we all work together on this problem we can clean up the situation. This organization can do no better work than to attack this pollution problem.

Mr. Wm. C. Adams, of Massachusetts. We are carrying on an interesting experiment in Massachusetts. It is a very large question, the extent to which pollution will keep fish out of a stream when they run up in the spring to spawn. We have in our state a vast water system, the Taunton River and its tributaries. For a number of years some of the fish ways on this river have fallen into decay. This last year The Connecticut Mills Company rebuilt, at its own expense, the fish way around its dam, which is the first obstruction to the run of the fish on the Taunton River. We have drawn the plans and provided the specifications for the installation of fish ways at all of the necessary points on that entire system.

It is argued that the fish have disappeared from this stream largely from two causes: first, the disappearance of fish ways and second, the presence of pollution in the streams. As far as the effect of pollution is concerned, it appears to be a mooted question throughout the entire United

States as to the extent to which it actually affects the fish upon the flood waters in the spring. We know that if there were no fish ways it would be impossible for a fish to get up. If the fish ways are there, and then they do not go up, it is certain that you can charge it to pollution, especially if the necessary steps are taken to see that the rivers are stocked in their upper reaches.

We have a very drastic pollution law in Massachusetts giving our commission very autocratic powers. We have been just as reluctant to invoke these laws in certain directions as has been intimated by Professor Ward. On the other hand, we do find there are two ways of getting at the thing. There is a certain class of corporations that are just wise enough to the political strategy of the times that they do not want to oppose public sentiment any more than they can help. A large number of these corporations will exploit a state asset in the shape of water power, but they do not want the thing uncovered. We find that class of corporations perfectly willing to cooperate with us whenever we, within reason, will point the way. There is another class of bad actors that will compel you to put the short rope on them before they will do anything.

In this pollution question it occurs to me that the commissions have a two-fold duty. It is a biological proposition and an engineering proposition. If we had in each one of our state commissions an engineering expert whom we could send into the X. Y. Z. Company and say, "Gentlemen, I come here from the State. Any communication that you make to me will be considered as a privileged communication. Our desire is to work with you in removing pollution. If you will reveal to us the character of your pollution and show us exactly how you handle it mechanically, we will undertake a constructive study to see what we can do in suggesting to you a plan by which you can eliminate it. The state will stand the expense in the first instance, because we regard this very largely as a state duty in clearing up public waters, and then we will map out and give to you our plan of constructive development." That will enable us to carry on our campaign of education with these men in the most subtle and indirect manner, because a practical business man at the head of one of these companies will look at consequences and results and he will be ready to help you all he can.

MR. GEORGE D. PRATT, of New York. Concerning the matter that Mr. Adams speaks of, in the conference we had last week these men said, "You tell us what to do." I said, "No, I will not, that's up to you." I told them it would take a force of men as large as the number we have on the Commission, over five hundred, to take care of all the different plants in the state. Take the pollution from tanneries; it is an entirely different question from the pollution from milk products, and pollution from lumbering is another proposition. They are all different. Now, they all have their own chemists, and it's for them absolutely to work it out. If we allow them to put that up to us, they are going to "pass the buck" every time. The way to work this problem out is to make them do it, and they will do it if they are made to.

Mr. W. H. Killian, of Maryland. It has been only a comparatively short while since I have been concerned with fish conservation and propagation, and in that short time it has dawned on my mind that the biggest problem we have is this very problem under discussion, and I feel very well repaid, so far as our work is concerned, if we do not have any other subject under discussion at this meeting. It has been dealt with by the states individually for a longer or a shorter period according to the activities of the state administrations charged with the matter, but it seems to me that very recently many of these big problems have become national problems.

The Food Administration has been accorded very autocratic powers of late, and the fact that this pollution is not only affecting the food production at the present time, but is going to be cumulative and far reaching, it appears to me should lead this Society to take some action to interest the Federal Government in the matter.

We are concerned with just the same proposition in Maryland that the several commissioners who have preceded me have spoken of. We have very drastic laws and made some progress in putting them into effect, until the Federal Government's own activities within our area, within the past twelve or fifteen months, have rendered the Government itself one of the greatest violators of our local laws. We find that when we approach them we have to deal with department heads assigned to the individual operations, who frankly tell us, "I get my instructions from Washington." Then we are "stumped," just as Mr. Buller stated in the case in Pennsylvania, where his legal department advises that no interference should be imposed. It has so seriously bothered us that we have felt under the necessity of taking it up with the Secretary of War, with the hope that if we could impress him with the proposition, some general policy might be laid down by him whereby the individuals dealing with the separate operations would at least be instructed to cooperate with the state officers where a conflicting problem arose.

If food is such a vital necessity in the conduct of the war as to make it necessary to establish a new branch of the government for handling it, it would seem to me that perhaps we should get a great deal of help if we could interest the U. S. Food Administration in this matter. Or, if we could address that appeal to the War Department, or any other department of the Federal Government that has activities that are adding to this problem that is troubling the various states, it would be the proper thing for this Society at this meeting to present the matter, and I hope that the resolutions committee will, before we adjourn, take some action in that connection.

Mr. W. E. Barber, of Wisconsin. I thoroughly agree with Commissioner Pratt of New York. I believe that these manufacturing institutions owe something to the people of the states in which they are operated. The only way to settle this question, in my judgment, is to have a good, stringent law with a heavy penalty, and let the chemists of those organizations work out the problem. We have had so much experience with the plants in our

state that we are thoroughly convinced the only way to get action is through a stringent law with heavy penalties.

We surveyed the plants of our state, and sent out letters to each one telling of the conditions and reciting the law on what was expected of them and what they must do. Some of the mills responded that they would investigate and see what could be done. One plant in particular, responded that they would refer the matter to their attorneys, and see what was necessary to be done. That's the sort of cooperation you will get on the part of some of them. We must insist upon our legislature passing laws that will make these men take care of the situation in each individual plant. It is preposterous to think that a state conservation commission or a board of health can spend its time or the state's money to survey each of these plants and then watch each individual to see that he obeys the law. These plants have men that can work out a system of disposing of waste in a way that will not pollute the streams.

In our state the chemical engineer from the State University, who is working with the State Board of Health, has looked over these plants, and made plans and blue-prints of a system for taking care of these industrial wastes and presented them to some of the firms. The law should compel those men to take care of their own business just the same as the manufacturers of the state that are not interfering with the public welfare take care of theirs.

Prof. J. G. Needham, of Cornell University. Concerning the discrepancy of views between Mr. Pratt and Mr. Adams. I think they are both right. It is entirely feasible, when information is available and a method is well known whereby pollution can be eliminated, for a commission to help a factory towards getting rid of it. But suppose it is an unsolved problem,—and most of the problems of pollution are still largely unsolved—it behooves us to compel factories to put a chemical expert on the job, for the chemical expert is trained for the productive side. In almost every case, he is not trained for such matters as are involved in the disposal of the waste.

There is a mode available to manufacturers, that is becoming more or less widely used, one end of which we see at the University in the industrial fellowship courses. A good many industries are appointing men to come to us for the necessary training for work in their institutions and factories, bearing directly on problems that have arisen in their factories. These men get the benefit of the conference of views, bringing to the problem all sorts of knowledge available in the University, and work towards finding a solution of the difficulty. That is industrial fellowship, a name borrowed from classic literature. They are simply investigators hired at first by the firms that need them. These industrial fellowships have resulted already in solving many problems of pollution, and of getting rid of wastes by turning them into something useful.

It has so come about in many cases that large interests have been involved, and that where a few people have supported a thing of this kind

for a year or two, the state has now taken it up and has furnished funds to continue the work. You may know of the fund that was provided by New York last year for the investigation of bean diseases. A few bean growers had worked on the problem for two or three years, and finding so many were affected and the prospect for results was so good, they took it to the legislature and got a foundation established to keep the work going. There is no reason why any group of industries with large problems of pollution on their hands should not avail themselves of outside help in this way, in case the men on their staff are not equipped for the study of those problems.

I have a friend here in the city who got up a course in the chemistry of paper making in the University of Maine a few years ago, a four years' course with all of the aspects of paper making treated which did not have anything in it about the disposal of the wastes from the paper mills to make them innocuous to the life of the streams.

Coming from an educational institution, I am greatly pleased to hear the educational aspects of this matter emphasized today, and I want to say that besides research, which is, of course, our large function, is a good deal of assistance that perhaps we can lend in this very thing. We have at Cornell one of the most complete arrangements for utilizing the enthusiasm of the youngsters in the schools that can be found anywhere. The school leaflets that are issued there cover all sorts of subjects of interest to children in the schools. There is no reason why we should not devote an early one of these to clean water and I will go back with the suggestions made here today and see that we do it at once. If we get the youngsters interested in keeping the streams clean, so they can fish and swim and have places of rest and recreation and where the beauties of nature can be enjoyed, we have gone a long way toward the solution of our problems. We love to call this country of ours "God's country," but it is not God's country any longer when it gets to be a place where you have to hold your nose.

RESULTS OF SOME TROUT FEEDING EXPERIMENTS CARRIED ON IN THE EXPERIMENTAL HATCHING STATION OF CORNELL UNIVERSITY.*

By G. C. Embody,
Assistant Professor of Aquiculture.

The rise in cost of the fresh meats commonly used in feeding trout has made it necessary to find something which might be substituted partly or wholly therefor. This was the chief purpose in initiating the experiments referred to in the present paper.

A trout food in general should meet two principal requirements: first, it should keep the trout in perfect health, rendering them less susceptible to the attacks of various diseases, and second, it should be efficient as a flesh or egg producer. That is, it should produce flesh of prime quality in the shortest time and with the least expense, or in the case of eggs, their quality, quantity and cost should constitute the essential consideration.

One must recognize, of course, that the food is not the only factor to be reckoned with in the production of fish flesh and fish eggs. Undoubtedly fish are much like poultry in that the ability of certain individuals to grow rapidly and produce eggs in quantity, is inherited and not acquired by the use of certain foods. Some individual trout may not grow rapidly nor produce eggs in quantity even if given the best known foods in abundance. Nevertheless fish cannot grow nor produce eggs of normal quality and quantity without proper food. Inasmuch as liver has been the most generally used food in trout hatcheries, it was thought desirable to compare any new foods with liver as regards the two principal requirements, health of the trout and efficiency of the food.

Several wooden troughs identical in size were set up in such a manner as to receive exactly the same volume of water per minute from the same source. Each trough was provided with a

* This paper was awarded first place by the American Fisheries Society for original work in fish culture.

cover which could be locked securely. The water always contained oxygen to the point of saturation. It was also rendered free from all food organisms by passing it through a settling basin and series of screens. Thus the conditions in each trough were identical with those of every other trough insofar as it was possible to make them.

Preliminary tests indicated that the most accurate measurements and observations could be taken only in comparatively small basins and with a small number of trout. Consequently, the troughs just described were made to hold a volume of water available to the fish, 3 feet long, 16 inches wide and 5 inches deep and the number of trout placed in each trough varied from 46 to 100 depending upon their size. A regular hatching trough 8 feet long and 14 inches wide was used for the chinook salmon fingerlings, while in the case of 2-year-old brook trout, a cement basin 8 feet long, 3 feet wide and 14 inches deep was found convenient.

All the trout were weighed in a glass vessel of water which had previously been balanced upon a set of standard laboratory scales. The trout were first taken out of the trough with a small dip net, allowed to drain one minute and then carefully placed in the glass vessel of water. The net was then lifted carefully out of vessel allowed to drain one minute into the same, and then the process was repeated until a sufficient number of trout were ready to be weighed. With this precaution the error due to adding or removing water was reduced to a minimum. Weights were always taken from 12 to 15 hours after feeding.

The experimental procedure consisted in (1) weighing trout at the beginning and end of each experiment; (2) feeding them once daily in the case of yearlings and twice daily in the case of fingerlings. The food was given slowly and in sufficient quantities only to insure entire consumption. Hence there was no waste to be deducted from the total weights as recorded. (3) Records were kept of the total food consumed during the experimental period; of the mean daily water temperature, and the mortality. In this manner a rather large series of data was obtained, the more significant of which are included in a table which follows.

FOODS USED.

Aside from beef and pig liver, the former used for comparison with other foods, the following products were tried:

Meat meal, known also as "animal meal" and "fish meal," is made entirely from scrap lean meat, dried and ground. It is put out in three grades—fine, medium and coarse—and retails for about 5 cents a pound in 100-lb. bags. It contains only a minimum amount of fat, is practically free from dirt and will keep indefinitely in a dry place. Meat meal is valued principally for its high protein content.

The fish meal used was manufactured from marine fish of species not placed on the market. It contained only about 10% fat and was kept for two years without deteriorating. The cost was approximately 4½ cents per pound.

Shrimp meal, commonly called "shrimp dust" or "shrimp bran," is the refuse from the Mississippi driers and canneries. It consists of the dried parts of shrimp and prawns not used for human food. It varies in texture from fine meal to coarse irregular pieces and will keep indefinitely in a dry condition. Although slightly deficient in available protein it contains a large amount of chitin, a substance that trout secure abundantly from many natural food organisms, in addition a large per cent of common salt, phosphates and lime. The cost is approximately 2½ cents per pound.

Peanut oil meal is the refuse from various manufactured peanut products. It is valuable alone for its high protein content. The retail price is about 2 cents per pound.

Red dog flour and wheat middlings are well known to fish culturists. It is only necessary to recall that the price of the former has advanced to about 3½ cents a pound and that of the latter to 3 cents. Both of these products have but little value as food for trout, but they were useful in experiments for the purpose of binding together the dried foods.

FOOD MIXTURES AND THEIR PREPARATION.

All fresh meats used in the experiments were prepared in the usual manner by grinding to the necessary degree of fineness for trout of various ages.

The following mixtures of the products mentioned above were tried:

I.

Beef liver	60%
Red dog flour	40%

II.

Beef liver	45%
Meat meal	45%
Flour	10%

III.

Beef liver	50%
Fish Meal	50%

IV.

Meat meal	35%
Fish Meal	35%
Flour	30%

V.

Meat meal	50%
Shrimp meal	30%
Flour	20%

VI.

Meat meal	40%
Shrimp meal	40%
Flour	20%

VII.

Meat meal	45%
Peanut Meal	45%
Middlings	10%

VIII.

Meat meal	85%
Liver and kidney	15%

In mixtures I, II and III, the flour and the various meals were merely stirred into the ground liver and fed directly. In IV, V, VI and VII, the various foods were first mixed dry in the proportion indicated; then boiling water was stirred in until a thin mush was obtained. This was allowed to cool, broken up into small pieces and thrown to the fish. In the case of mixture VII, the meat meal was made into a mush in the manner just described and fed six days each week. On the seventh day a mixture of equal parts of liver and kidney were fed alone in the usual manner. This actually amounted to the proportions indicated even though the meal and fresh meat were not mixed when fed. In feeding meat meal alone to advanced fry and small fingerlings, the meal was sifted to eliminate coarser particles and the fine siftings were merely sprinkled over the surface of the water in a dry condition.

The numerical results of these experiments are condensed in the following tables. The figures to be noted chiefly are those expressing the efficiency of the food, the cost of food necessary to produce one pound of fish, and the mortality.

The efficiency factors are used to express the relation between the gain in weight of trout and the amount of food consumed. The direct factor is found by dividing the weight of food consumed during the experiment period, by the gain in weight of the fish for the same period. It merely states directly how many

pounds of food were required to produce one pound of fish. The reciprocal factor is found by dividing the gain in weight of fish by the weight of food consumed and expresses the fraction of a pound of fish produced by one pound of food. The direct factor is very convenient for calculating the cost of the food used in producing a pound of fish. It is only necessary to multiply this factor by the cost of the food per pound. Thus, in the first table, in the case of beef liver, the average direct factor for a period of 70 days was found to be 3.16. Multiplying this by .12, the cost of beef liver per pound, we find that the cost of producing a pound of fish was $.379. It will be seen that the higher the direct factor the greater will be the cost of the fish. In the case of the reciprocal factor, the higher the factor, the lower will be the cost of the fish.

The mortality as recorded in the table represents the number of deaths occurring each week in per cent of the total number of fish used in the experiment.

Comparing the various food costs for producing a pound of fish, it may be seen that the highest costs occur when liver is used alone or in combination with flour—series A, B and C. As the amount of beef liver is lowered so is the cost of production lowered. Except in the case of chinook salmon, where the food mixture contained only 15 per cent liver, we find the four lowest costs to have been obtained with mixtures containing no liver—series F, G, H and I. In not one of these four series, however, was the experiment period longer than 36 days and hence further trials may change the figures to some extent. This is particularly true in the case of the meat meal-fish meal-flour mixture. Nevertheless the average of costs in the four cases—10c—is low enough to indicate clearly the high food value of these dried meals. Outside of series F, where the production cost of 6 cents is undoubtedly too low, the most economical mixtures seem to be those containing meat meal and shrimp meal with a small amount of flour for binding the mass. This is indicated in the two series, G and I, where the production costs are about eleven and one-half cents in the former and a little under eleven in the latter.

The trials with the meat meal-peanut meal-middlings mixture, series H, were so high that it was thought best to test peanut meal alone. The same fish used in series H were fed a mixture of

Peanut Meal.......90%
Middlings..........10%

This was made into a mush and fed in the usual manner. After 15 days of this ration, the trout lost 8.9% of their weight and were subsequently attacked by fungus which killed about 50% of the fish before it could be checked.

This is a rather striking indication that the protein in peanut meal is practically indigestible in the case of trout and since it served no useful purpose, it was thought best to dispense with it altogether.

MORTALITY.

The true state of affairs regarding mortality is not indicated clearly by the tabulated figures except possibly in the case of mixtures containing a large per cent of beef liver. During the past three years of experimentation, it can be said that no abnormal death rate has ever occurred when beef liver was used in mixtures to the extent of 45% except where the loss could be directly attributed to causes other than the food. This cannot be said of mixtures containing the dried products alone. Continuous feeding of these in nearly all cases eventually resulted in a high mortality. The period before the mortality began varied from one to three months depending upon the age and species. In general fingerlings were more susceptible than yearlings and older trout, and rainbow trout were less resistant than brook and brown trout. In nearly all cases this high mortality could be checked in the course of two weeks by changing to a diet of some fresh meat. Liver, lean meat, kidney or melts were all equally effective in bringing about the change. This discovery has led directly to our recent practice of feeding one ration each week consisting of some fresh meat alone and on the other six days using various mixtures of meat meal, shrimp or fish meal, together with a small amount of middlings as a binder.

During the present year, only, have we been successful in using any of these dried foods for rearing advanced fry to fingerlings. In the case of some chinook salmon, ground liver and kidney was fed twice daily in alternation with three daily feedings of meat meal. The latter was first sifted to remove the coarse particles and then merely sprinkled over the surface of the water. The salmon took this readily from the surface and usually cleaned up that which sunk to the bottom. The total mortality from the

time feeding began until the salmon averaged two inches in length was about 20%. Since that time the amount of liver and kidney has been reduced to one ration a week, the other daily rations consisting of meat meal alone. The results with this food are shown in Series J, of the table.

CONCLUSION.

These experiments must not be considered as finally disposing of questions concerning the use of these foods for trout. They are rather preliminary to a much larger series contemplated. Therefore, it is perhaps wise not to draw too narrow conclusions at this time. However, it seems not unreasonable to believe that the cost of rearing brook trout may be materially lowered by the partial substitution, at least, of some of the dried meals mentioned, for certain of the high priced fresh meats now in use.

ACKNOWLEDGMENTS.

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TABLE OF DATA ON FEEDING EXPERIMENTS UNDERTAKEN AT CORNELL UNIVERSITY, 1915–1918.

Food Used and Cost Lb.	Age of Fish in Months	No. of Fish	Exp. Period in Days	Av. Daily Consumption in Terms of Perct. of Wt. of Fish	Efficiency Factor Direct	Efficiency Factor Reciprocal	Cost of Food to Produce 1 Lb. of Fish	Ave. Mort. % Weekly	Ave. Daily Water Temp. C.	Series
Brook Trout.										
Beef liver $ .12	16	46	14	4.65	3.89	.257	......	.....	12	A
	16	46	14	4.69	3.1	.3137	......	.....	13.5	
	17	46	14	3.8	3.4	.287	......	.....	15.5	
	18	46	14	4.2	2.89	.346	......	.....	15.8	
	18	46	14	4	2.56	.39	......	.....	16	
	16–18	46	70	4.27	3.16	.3187	.379	0	14.5	
Brook Trout.										
Pig liver $.10	11	65	14	3.	5.	.20	......	0	4.8	B
	12	65	14	1.65	3.89	.257	......	0	5.	
	14	95	14	2.3	3.36	.297	......	1.5	6.3	
	14	93	14	1.7	4.	.25	......	0	7.7	
	15	93	14	5.17	4.	.25	......	0	9.5	
	11–15		70	2.76	4.05	.2508	.405	.3	6.6	
Brook Trout.										
Beef liver 60% Flour 40% $ .086	16	46	14	4.55	6.8	.146	......	.....	12	C
	17	46	14	5.69	3.8	.261	......	.....	13.5	
	17	46	14	3.9	3.7	.268	......	.....	15.5	
	16–17		42	4.71	4.44	.225	.382	0	13.6	
Brook Trout.										
Beef liver 45% Meat meal 45% Flour 10% $ .106	16	46	14	2.86	2.9	.344	......	.....	12	D
	17	46	14	2.83	2.17	.46	......	.....	13.5	
	17	46	14	2.8	1.89	.528	......	.....	15.5	
	18	46	14	2.45	1.68	.595	......	.....	15.8	
	18	46	14	2.24	1.62	.615	......	.....	16	
	16–18		70	2.63	2.	.508	.212	0	14.5	
Brook Trout.										
Beef liver 50% Fish meal 50% $ .082	16	46	14	3.56	3.36	.296	......	.....	12	E
	17	46	14	3.87	2.19	.456	......	.....	13.5	
	17	46	14	3.27	2.08	.48	......	.....	15.5	
	18	46	14	2.35	1.78	.56	......	.....	15.8	
	18	46	14	2.1	1.58	.63	......	.....	16	
	16–18		70	3.05	2.19	.485	.179	0	14.5	
Brook Trout.										
Meat meal 35% Fish meal 35% Flour 30% $ .043	18	46	14	1.5	1.8	.55	......	.....	15.8	F
	18	46	14	1.5	1.3	.77	......	.....	16	
			28	1.5	1.5	.66	.06	0	15.9	
Brook Trout.										
Meat meal 50% Shrimp meal 30% Flour 20% $ .039	24	133	14	2.6	3.3	.30	......	.....	3.7	G
	24	133	13	1.46	2.64	.374	......	.....	4.5	
			27	2.03	2.97	.337	.1158	0	4.1	
Brook Trout.										
Meat meal 45% Peanut meal 45% Middlings 10% $ .035	8	63	15	3.7	3.84	.26	......	2.3	10.26	H
	8	61	15	2.4	4.87	.205	......	0	8.8	
			30	3	4.35	.2325	.152	.57	9.5	
Brown Trout.										
Meat meal 40% Shrimp meal 40% Flour 20% $ .037	17	80	18	2.18	3.22	.31	......	2.1	14.2	I
	18	62	18	2.4	2.63	.379	......	2.	14.7	
			36	2.29	2.92	.344	.108	2.	14.4	
Chinook Salmon.										
Meat meal 85% Liver & kidney 15% $ .059	4	1000	14	2.7	1.82	.5478	......	2.2	12.3	J
	5	1000	14	2	2.6	.377	......	.6	13.4	
	6	1000	28	4.1	2.8	.352	......	5.	14.5	
			56	2.9	2.4	.426	.1416	1.9	13.4	

STUDIES ON THE NUTRITION OF FISH: EXPERIMENTS ON BROOK TROUT.*†

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Metabolic studies on aquatic animals have not been numerous. The inherent difficulties of collecting the excreta and measuring accurately the consumed food, both of which are soluble in the water, have doubltess made this subject unattractive to investigators.

In undertaking a nutritional study on the brook trout—a fish remarkably sensitive to slight changes in its environment—the first problem to settle was the practicability of keeping these animals in small aqauria. The trout thrive in rapid streams, and the problem would evidently be beyond solution if they could not be kept in good health in a limited quantity of water. Experience has shown that with sufficient aeration, trout can be kept in as little as four or five liters of water, which need not be changed but once every forty-eight hours, or even at longer intervals. Under such circumstances the trout will not only remain in good condition, but as the experiments here recorded show, will gain weight.

Large museum jars of about twelve inch diameter were used as aquaria, and these offered the fish considerable room for swimming and could be maintained very clean. The jar was closed by a cover which could be clamped tightly to the bottom, and by means of a flat rubber ring the joint was made air-tight. Two round holes drilled in the cover of the jar were fitted with rubber stoppers. Through one of these the aeration tube was passed, while in the other a specially designed cup was inserted containing a measured quantity of standard acid. Compressed air was blown

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through the water and was dissipated as a fine spray by the aeration tube. The air escaping from the jar bubbled through the standard acid contained in the cup. This precaution was taken in order to avoid any possible loss of ammonia from the water by the vigorous current of air.

The contents of the cup were emptied every twenty-four hours and titrated with $\frac{N}{100}$ sodium hydroxide. As no changes in the quantity of acid have been found in the course of many trials, this practice was discontinued as unessential to the accuracy of the experimentation.

The aquaria were submerged in a trough of galvanized iron through which a constant circulation of water of fairly uniform temperature was maintained. The temperature of the aquaria in which the trout sojourned was thus regulated.

The water used in these experiments was exceptionally pure, coming directly from the excellent filters installed in the New York Aquarium. No sediment was formed by this water even upon standing several weeks.

The trout which were experimented on were weighed at the beginning and close of each period. Different methods were tested for obtaining the accurate weight of the fish, and finally the following method was adopted: The trout was picked up with a small, fine net, the adhering water shaken off and allowed to drain for about half a minute. The fish was then transferred cautiously to an aluminum can partly filled with water, the weight of which was accurately determined. With practice it was possible to perform this operation without splashing a drop of water. The can was closed and again weighed with the trout, whose weight was thus gotten by difference. Though the method is not free from certain defects, it had two important advantages over every other method tried, in that, in the first place, no injury was done to the trout; and secondly, with the animal securely in the can, the weighing could be done leisurely. Of course it is assumed that the amount of moisture adhering to the animal has been the same at each weighing. Though this assumption is arbitrary, it has been found, by weighing the animals several times in succession, that the extreme differences do not vary

more than 0.5 per cent. The balance employed in all weighings was sensitive to a milligram with a load of one and one-half kilogram.

Feeding the trout was unquestionably the most difficult and yet the most essential step in the process of accurately measuring their metabolism. The effort, therefore, was made to teach the fish to take their food directly from forceps. Wherever this was feasible, the rest of the experimental procedure was quite simple. In a few instances I was actually successful in so training the trout that they would come to the edge of the aquaria and leaping out of the water, snap the food held with pincers. In this way the washing out of soluble constituents of the food by the water was entirely prevented.

The food was kept in small weighing bottles, and the amount consumed was determined by the difference in the weight before and after feeding. The method of feeding the trout ***ad libitum***, had the advantage also that at no time were there unconsumed particles of food left in the aquaria which might favor contamination of the water, and thus greatly affect the significance of the results.

Unfortunately this method of direct feeding could not always be utilized, as will be shown in a later section. The food was generally prepared in large quantity and stored in a frozen condition. The contents of every jar was carefully analyzed, and its composition was checked at least twice in the course of an experiment. Portions of this stock food, enough for several feedings, were put in weighing bottles, and kept in the ice chest in the laboratory.

Usually forty-eight hours after feeding, the trout was removed to a jar with a fresh supply of water, and the old water containing the solid and dissolved excreta of the preceding period was filtered and prepared for analytical treatment.

Large aluminum tumblers, the bottoms of which were perforated with a number of fine holes, were used for this purpose; the tumblers serving as Gooch crucibles. The tumblers were provided with a thick pad of fine glass wool, dried in the oven and weighed. The contents of the aquarium were siphoned into the tumbler and filtered through the glass wool, with the aid of suction, into a large bottle. The glass wool was found very efficient in

retaining even minute particles floating in the water, but the filtered water showed invariably a distinct turbidity. The tumbler with the solid excreta retained in the glass wool was again dried and weighed; thus the weight of dry feces was gotten by difference.

It may be mentioned that the sides and bottom of the aquaria were thoroughly cleaned with a rubber tipped rod, and the wash water added to the filtrate. This was acidified with five drops of sulphuric acid and evaporated to a small bulk. As a rule, the final volume was made up exactly to one liter.

In view of the large quantities of water that it was necessary to handle, the matter of evaporation presented certain technical difficulties. Originally it was attempted to carry out the evaporation at a low temperature (50° C.) with the aid of a rapid current of hot air. This method was very cumbersome, requiring much time. Blank experiments have shown that there was no particular advantage derived from the use of a low temperature. A large steam bath was therefore installed, accommodating a number of evaporating dishes (white enamel) of about twelve liters capacity each. The steam bath was set in the apparatus previously used for evaporating by means of the current of dry air, so that the two methods could be combined at will. Very large quantities of water could in this way be quickly condensed to a small bulk. The condensed water was transferred to a volumetric flask, the evaporating dish thoroughly rinsed with fresh water, and the quantity brought up to a definite volume. This condensed water was again filtered through asbestos to remove such particles as may have gone through the glass wool. This quantity was negligible, but the amount accumulated in the course of an experiment was analyzed and added to the feces. Aliquot portions of the perfectly clear water were used for analysis.

In choosing fine glass wool as a means of separating the solid excreta from the water, two important considerations were borne in mind; owing to the small quantity of feces available, it was very difficult to analyze it, and particularly to obtain a uniform sample. It was urgent, therefore, first to mix the feces with some other material to increase its bulk without interfering with the analysis, and secondly, to make the grinding of the feces possible.

The use of glass wool for this purpose suggested itself after a number of different things have been tried with little or no success.

The glass wool proved particularly ideal as it served as a filtering medium, and could be ground to a thin powder, helping to reduce the feces to a state of extremely fine sub-division and uniform distribution.

These powders, in which the glass represented many times the bulk of the feces, were kept in weighing bottles and were easily sampled for analysis. Nitrogen and fat determinations were made on weighed portions in the usual manner. It may also be mentioned that blank experiments were performed, and the analytical data furnished corrections for the dissolved excreta and feces which were found in experiments with trout.

EXPERIMENTS IN FASTING.

As a preliminary to the feeding experiments, a number of experiments were performed on fasting trout. It has been found that the alimentary tract usually frees itself of all excreta from previous feeding in forty-eight hours. Minute quantities were sometimes eliminated also during the next twenty-four hours, but this was invariably negligible; the fasting, therefore, was generally started forty-eight hours after the last meal. The first protracted fast was performed with a trout weighing 102.9 grams (F-1). In the course of the four weeks of the experiment, no solid excreta were eliminated. The water in the aquaria remained remarkably clean for days, so that it could be changed at long intervals. The nitrogen eliminated in the water was determined for seven-day periods. After twenty-eight days of fasting, the trout weighed 95.7 grams or 7.2 grams less than at the start. The nitrogen eliminated during the first week of fasting was 67.2 mg., but the quantity diminished from week to week, only 45.1 mg. being eliminated during the last week. The average elimination of nitrogen per day and kilogram of weight was 81.3 mg. In the course of four weeks 233.5 mg. of nitrogen was lost. It is evident, therefore, that about one-fifth of the body loss was at the expense of the protein.

The next two experiments were made with trout which had been kept previously in the stock tank and fed freely. When transferred to the experimental aquaria, these fishes vomited much undigested food, and for a few days continued to eliminate large amounts of feces. Trout F-2 in the first week of fasting lost 4.6 per cent of its weight, eliminating 141.9 mg. of nitrogen per day

and kilogram. This very high nitrogen elimination was followed by a decided drop in the next week, when it was only 71 mg.; the loss in weight at the same time having been reduced to 1.3 per cent. During the entire two-weekly period of fasting 5.9 per cent of the body weight was lost, and the daily nitrogen elimination per kilogram of fish was 105.5 mg. The very high nitrogen elimination during the first few days of fasting which, in this case, was preceded by abundant and unrestricted feeding, will be observed in several other experiments. This condition is met with also in the case of the higher vertebrates.

In experiment F-3 it will likewise be observed that the nitrogen elimination reached a very high level of 132.2 mg. per day and kilogram, but the fast was not continued further with this animal.

Experiment F-4 presents essentially the same picture. This trout was used in a long feeding experiment, and for weeks it was fed regularly and *ad libitum*. It was then subjected to a fast of two weeks' duration, during which time it had lost 9.3 per cent of its weight. The nitrogen eliminated in the first and second week shows that it was twice as large during the former, being 155.9 mg. nitrogen per day and kilogram for the first seven days, and only 79.3 mg. for the next seven days. This large loss of nitrogen observed invariably upon changing from an abundant diet to fasting, especially in the case of trout F-4 which for a month previous to the fast has been eliminating a fairly constant amount of nitrogen daily, brings up again the question of the circulating protein which, when the income of new food material is stopped, is the first to be consumed.

Experiment F-5 like the first of the series, is interesting because this trout was not on an abundant diet previous to the fast. Its nitrogen elimination for eight days was 91.6 mg. per day and kilogram of body weight. We may regard, therefore, the elimination of 80 to 90 mg. per day and kilogram as the normal nitrogen catabolism of the Brook Trout. (See Table I.)

FEEDING RAW BEEF HEART.

Raw beef heart cut in fine strips about one cm. long was fed directly from forceps. The results of an experiment which lasted over two months are recorded in Table II. During this time the excreta for every forty-eight hours were collected and analyzed

separately. In the course of the first month, it will be seen, the trout gained 77.3 per cent in weight. It consumed 85.34 grams of beef heart, and the excretion from day to day showed remarkable constancy. It will be noted also that the amount of nitrogen in the feces was almost invariably 10 per cent of the dry fecal matter, and this proportion coincides with that found in the feces of mammals on a pure meat diet. The dry feces constituted about 5 per cent (Table VI) of the dry material ingested with the food. The utilization of the food—protein and fat—has been almost constant throughout this part of the experiment. Of the 2.8981 grams of nitrogen fed, 0.9329 grams was retained. In the absence of experiments on the respiratory exchange, the retention of fat could not, of course, be worked out. Considering the amount lost with the feces, 96.1 per cent of the consumed protein was utilized, and 94.5 per cent of the fat. Not only has the utilization of the food through digestion been good, but as the "Index of Growth" (ratio between increase in weight and quantity of consumed food per kilogram and twenty-four hours) will show, it furnished a considerable proportion of its material to the building up of the body tissues.

The consumption of the trout per day and kilogram of weight amounted to 37.5 grams of food, while the increase in body weight per day and kilogram was 17.4 grams. In other words, 46.5 per cent of the food material was added to the organism (See Table VI). The trout was then allowed to fast for a fortnight, (F-4, Table I), in order to find out how this would affect the digestive power and general condition of the animal whose metabolic exchange had been carefully established by the previous study.

Upon resuming feeding, the trout gained 15.7 per cent in two weeks. During the first four days of re-alimentation, the very small amount of nitrogen in the water (urine) is very marked. During the first part of the experiment, the urinary nitrogen represented on the average 63.9 per cent of the total nitrogen consumption, but during the first and second forty-eight hours following the fast, it was 39.7 and 57.2 per cent respectively. There was thus undoubtedly a retention of nitrogen. As the elimination for the next forty-eight hours shows, this this retention was only temporary.

During this third two-day period, the urinary nitrogen represented 106.1 per cent of the consumed nitrogen. In other words, the nitrogen ingested since the fast was broken, was not excreted until six days later. The nitrogen elimination then gradually diminished, but even after two weeks, it was still 10 per cent higher than in the first part of this experiment.

An examination of the feces also revealed that the amount of dry excreta has become 50 per cent greater than during the preceding period, and furthermore that the feces became very fatty, in fact from the fifth until the tenth day of resumed feeding, the per cent of fat was extremely high; this apparently being due to delayed elimination of undigested fat rather than to a progressive impoverishment of the digestive functions. In this respect there is almost a direct relationship to the excretion of urinary nitrogen. The utilization of nitrogen during these two weeks was 94.8 per cent, not essentially different from the degree of utilization in the pre-fasting period, but the fat utilization was only 91.7 per cent.

That the general condition of the trout was impaired by the starvation, is indicated best by the lowering of the "growth index" (See Table VI). During these fifteen days the trout received 26.7 grams of raw beef heart per day and kilogram of body weight, but it gained only 9.73 grams in weight; in other words, the "growth index" was 36.5 per cent as compared to 46.5 per cent of the earlier part of the experiment.

The experiment recorded in the next table presents much similarity to the preceding one. Six small fingerlings weighing all together only 33.6 grams, were used. During the first part of the experiment lasting twenty-six days, these small trout were fed thirteen times and the excreta were collected and separately analyzed four times during that period. A glance at the tabulary summary (III) of the results will show that the animals consumed 25.41 grams of the raw beef heart, and gained 11.13 grams in weight. The quantity of dry feces eliminated in that time was 3.52 per cent of the total dry ingested food, and contained 21.2 mg. of nitrogen. The protein of the food, therefore, was utilized to the extent of 97.5 per cent, and the fat 96.2 per cent. The "index of growth" was 42.7 showing that the fingerlings were growing at a favorable rate.

Owing to the accidental death of one of the experimental animals, the experiment was renewed with the five remaining

survivors, and continued for another twenty-one days. During this time the excreta were collected and analyzed five times. A short fast of four days intervened between the first and second part of this experiment. The composite weight of the five fingerlings was 34.8 grams, and these increased 11.3 grams in the twenty-one days, or considering the average weight at the beginning and closing of the entire experiment, the fingerlings gained about 66 per cent in weight.

By reviewing the data pertaining to the second part of the experiment, certain differences will be observed as compared with the results obtained in the first part, which to a certain extent substantiate the experience gained in the preceding experiment 000.5.

In the first place the ratio of dry feces to the dry matter of food is 50 per cent higher, and this increase in the fecal discharge runs parallel to the diminished utilization of the nutriment. The conclusion, therefore, is warranted that in this instance also the digestive activity was somewhat impaired by the short fast. The growth capacity, was not affected in this instance, the fingerlings having grown more in the three weeks following the fast than during the twenty-six days preceding it. The gain in weight represented 49.8 per cent of the quantity of food per day and kilogram, as compared with 42.7 of the earlier period.

Two things must be borne in mind in connection with these experiments: In both instances the evidence clearly indicates that fasting is deleterious to the digestive function of the trout. The difference in effect upon subsequent growth may probably be due to the fact that in experiment 000.5, the intervening fast was a much more protracted one.

The last experiment on the effect of feeding raw beef heart is particularly interesting, as this was performed on the trout which had undergone a preliminary fast (F-1). In the course of fifteen days of the experiment, this trout consumed 27.71 grams of food with a content of 7.047 grams of dry matter. Examining the last three vertical columns of Table IV, the thing which strikes one's attention at once is the high proportion of fat in the feces; then the apparent retention of nitrogen as is shown by the low nitrogen content of excretions passed during the first several days after

feeding was resumed. That the retention was purely temporary is seen from the fact that within the next few days the elimination was abnormally high, especially between the sixth and ninth day when it became actually 30.8 per cent more than the nitrogen contained in the food for that period. This delayed elimination of nitrogenous waste points to the possibility that the excretory mechanism of the trout suffered an injury in consequence of starvation, which it required several days, when food was given, to restore to normal functioning.

The similarity of the results obtained in these three experiments is very striking, those of 000.5 and 000.7 being practically identical.

The dry feces formed a much greater per cent of the dry matter consumed with the food, than in any of the previous experiments (9.95 per cent). The utilization of the protein during the entire fifteen day period is 94.4 per cent, which compares very favorably with the extent of utilization observed in the other experiments. The utilization of the fat which has been reduced to only 83.8 per cent demonstrates once more, and more poignantly than in any of the previous experiments, the particularly deleterious influence of fasting upon fat utilization. The reason for this must unquestionably be looked for in the longer duration of the fast. To explain these facts it may be necessary to assume that a more lasting damage was done to the glandular structures of the animal, the pancreas and the liver, which lead to a defective digestion and absorption of fats. Further investigation of this question would at any rate be desirable.

In spite of the low degree of utilization of the food materials, the "Index of Growth" was 50.1; in other words, half of the nutrient material fed has actually gone towards the building up of the body tissues. This result is of much significance, inasmuch as it adds further proof for the idea that neither the utilization of the food in digestion, nor indeed the actual quantity consumed, determines the extent of the resulting growth of the organism. The trout in this experiment increased in weight at a greater rate than in any other of this series, while actually consuming the smallest quantity of food.

FEEDING COOKED BEEF HEART.

In the practical feeding of fish in hatcheries, the question is frequently asked, "shall the food be fed raw or cooked?" The objection to cooked food on the ground that it is not the natural condition of the fishes' nourishment, may well be dispensed with. Feeding fish in hatcheries is a problem in domestication, and the merits of a dietary system must be judged not by whether it resembles or deviates from the state of things in nature, that is, wild nature, but by the results which can actually be achieved with it. To anticipate what will be brought out in the description of the following experiments, cooked food is neither more nor less utilized than the raw food, though possibly it has less growth-promoting quality. For one thing it is not as palatable to the fish as the raw food, and in my experience, the trout ate it much less willingly and in smaller amounts. In only one respect does feeding of cooked food present a decided advantage. On raw food the feces are gelatinous and fairly massive, while those resulting from cooked food are more or less dry and scanty. The feces therefore have no tendency to adhere to the sides of the aquaria, being in well formed compact masses. Contamination of the water was, therefore, never observed when cooked food was fed, and it remained remarkably clear for a number of days.

The food was put up as before, except that it was brought to a quick boil with a small volume of water, the fluid completely drawn off, and the meat packed in stock jars, refrigerated and analyzed as usual.

Experiment 00.2 was made on the same trout which served in experiment 000.5. The result of these two experiments are, therefore, well suited for comparison. The animal was fed on the cooked beef heart for a considerable time to get it thoroughly accustomed to this food before the actual metabolic study was begun. The trout did not relish cooked food, and at best would eat only small quantities. In the thirty-eight days which this experiment lasted, the trout consumed only 23.9 grams of the food; the feces for this period contained 51.9 mg. nitrogen and 34. mg. of fat. These two constituents of the diet were therefore utilized to the extent of 95.7 and 96.1 per cent respectively, which is very close to the values (96.1 and 94.2) which were found on

raw meat. The per cent of nitrogen and fat in the dry feces is much greater than on a diet of raw meat, and this condition is very general as can be seen by comparing the data in columns 5 and 6 of Table VI. This very high percentage, however, is of no significance, being merely due to the fact that the feces is more compact and dry when the trout are kept on the cooked meat regime. It is more significant that the amount of dry feces presents the same proportion of the dry matter of the consumed food (3 to 4 per cent) no matter whether the food has been cooked or not.

The results of experiment 00.3 are essentially the same, though this trout has shown a somewhat smaller increase in weight. Experiment 00.4 which lasted forty-eight days, was made on a trout which had been fasting a week before the experiment commenced. The protein of the food was utilized as usual—95.7 per cent—but only 92.5 per cent of the fat was utilized. This is further confirmation of the point emphasized already on several occasions in this paper of the defective utilization of fat by trout that have undergone even a brief starvation. The amount of food this trout ingested per day and kilogram of body weight was 10.11 grams. The daily increment in weight per kilogram was 4.25 grams; in other words, the growth index was 42. When we compare the relative value of cooked and raw meat as the diet for trout, we can indicate the following advantages of the latter: Its greater palatability and greater growth-promoting quality. This can be seen at once when the average "growth index" of the experimental series 000.5 to 000.7 which is 45, is compared with the same of the experimental series 00.2 to 00.4 which is only 39. This might perhaps be objected to on the ground that the difference in the body weight increments is due rather to the great difference in the quantity of food which the trout have consumed in these two series of experiments. It must be recalled, however, that the "growth index" does not furnish information as to the actual or absolute increment in body weight, but indicates the fraction of the nutrient material which has become permanently incorporated as a part of the organism. The two kinds of food have been apparently ample in amount to insure not only maintenance, but a further increase in weight, but in the case of the cooked beef heart a smaller relative increase in body weight was secured.

It is possible that the lesser effect of the latter in producing growth was due to the fact that in the process of boiling, some of its "water soluble" growth-stimulating stuffs have been dissolved out. The fact that the food which has been boiled and thus lost a large part of its water content was as well utilized by the trout as raw meat, suggests that it would be practicable to utilize thoroughly desiccated food as trout diet. This soaked in water before feeding would probably retain both its gustatory quality, as well as its growth-promoting quality. This could doubtless become an excellent method for preparing on a large scale and distributing the food for trout hatcheries. Experiments which were planned with a view of studying the metabolic value of such desiccated foods, remained unperformed owing to the unexpected interruption of the investigation.

FEEDING BEEF LIVER.

Beef or pig liver is one of the staple diets in trout hatcheries, and a series of experiments were started to study its nutritive value. The liver was freed from all blood vessels and ducts, and the parenchyma alone was frozen solid and ground in a meat grinder to a fine pulp. The food was then kept in the refrigerator and analyzed as usual. Unfortunately it was impossible to feed this food directly from forceps as was done with the beef heart. It was necessary instead to throw a quantity of food into the aquaria and leave it there for a half hour. The trout was then removed to another aquarium with fresh water, in which the excreta were collected, while the unconsumed food was collected over glass wool in a large filtering tumbler. The filtrate was made up to a definite volume, of which aliquot portions were used to determine the nitrogen, fat and sugar that was dissolved out from the food by the water. The solid residue was dried at 100°, powdered and the composite sample for the entire experimental period was analyzed in the usual way.

Knowing the quantity of food thrown into the aquarium, the amounts of nitrogen, fat and carbohydrate were computed from the analytical data pertaining to the particular food sample. From this was subtracted the amounts of nitrogen, fat and carbohydrate both dissolved in the water and found in the solid residue.

The amount of each constituent consumed was then determined by the difference.

In his study of the digestion of fish, Knauthe* made use of this method exclusively. Apart from the disadvantage which it shares with all indirect methods, the method is time-consuming and presents so many unforeseen difficulties as to render the results at times valueless.

In the matter of recovering the fat, Knauthe's procedure, though very simple, consisting merely in extracting an aliquot portion of the water with ether, on closer examination proves of little or no value. Knauthe has not performed blank experiments to determine how closely the recovered amount corresponded with that washed out by the water; he therefore had no occasion to be apprehensive about the acceptability of his results.

As was pointed out in an earlier section, I considered the performance of blank experiments as very essential, and have relied on these in deciding whether or not the analytical procedure in use was adequate. By following Knauthe's method, I found that the results were so widely off the expected value as to make them absolutely worthless.

It will be noted further that in all the experiments, the animals were allowed to remain in the feed jars one-half hour, after which they were removed to fresh water. Knauthe on the other hand, allowed his animals to remain in the aquaria containing food for a very long time, and separated mechanically the feces from the solid food particles. It need hardly be pointed out that such a procedure is altogether too crude to warrant great confidence in the significance of experimental results. The bacterial growth in suspensions of nutrient material would be sufficient to vitiate the results. In a number of blank experiments a weighed quantity of liver pulp was put in the aquaria (without trout), left there a half hour as usual, then the solid residue and the filtered water were analyzed. In the case of the nitrogenous material and the sugar, the recovery was complete within less than one per cent, but in the matter of the fat, as determined by direct extraction of the water with ether, such low values were usually gotten as to render the data of no importance. The need of a different and

*Zeitschrift f. Fischerei, Vol. 6, p. 139, 1898.

better method was keenly appreciated, and attempts in this direction were started. The main difficulty to be remembered, was in the fact that the relatively small quantity of fat had to be recovered quantitatively from a large bulk of water.

All the determinations were in duplicate. The nitrogen was determined by the Kjeldahl method, and one-tenth portions of the entire water were used for the analysis. The sugar was determined by Bertrand's method in one-quarter portions. The sugar analysis was made on the perfectly clear filtrate, which was obtained by treating the water with aluminum cream to free it of the protein. On extracting this clear filtrate with ether, I invariably found that there was no fat present. This suggested a method of determining the fat, which is evidently carried down with the aluminum precipitate. By drying this voluminous gelatinous precipitate, powdering it and extracting it with ether, it was hoped that accurate results on the fat suspended in the water would be obtained. While this method, or some similar modification of it, has good possibilities, a number of difficulties were encountered in its practical application, which were not entirely removed before this work had come to an unexpected halt, and the matter of utilization of the fat from liver remained untouched in this investigation.

The feeding of liver has not met with success in my hands. A number of circumstances have probably conspired to make these experiments less definite than those of the preceding series. Many experiments terminated in failure, owing to the death or ill condition of the trout. Three experiments are recorded in Table VII, and these will perhaps throw light on the question of liver as a trout food. It will be seen that the trout did not grow as well as those fed on beef heart, indeed one specimen lost 8.5 grams. The utilization of protein (nitrogen) was very low (90.5 to 83.6 per cent). The utilization of glucose shows likewise wide fluctuation from 96.9 to 86.9 per cent. The utilization of the fat ranged about 90 per cent, but as the analytical data were not entirely reliable, these results have not been included in the table.

Before concluding, one other point should be mentioned. In the course of the half hour during which the liver pulp remained in the aquaria, as much as 60 to 75 per cent of its nitrogenous

material had been dissolved by the water. It is a conservative estimate that 50 per cent of the fat was washed out, and none of the glucose was left in the residue, it having been entirely dissolved out by the water. This happened in spite of the fact that the food was contained in a limited quantity of water, agitated only by the swimming movements of the trout.

In hatcheries where the trout are kept in rapid streams of water, it is questionable if a food which will so easily give up its components to the water, is a particularly valuable diet. Its inferiority to beef heart as a dietary article for trout is amply demonstrated by the results of the experiments here recorded.

TABLE I. Experiments in Fasting.

No. of Experiment	Period of Fasting	Av. Temp. of Water	Weight		Loss in Weight	Total N. Excreted	N. Excretion per Day	N. Excretion per Day and kgm.	Fat Excretion (Total)	Fat Excretion per Day and kgm.
			Initial	Final						
		° C.	g.	g.	%	g.	g.	g.	g.	g.
F–1	I.25–II.I	16.3	102.9	....	....	0.0672	0.0096	0.0941	....	....
	II.I–II.8		....	....	....	0.0629	0.0090	0.0900	....	....
	II.8–11.16		....	....	....	0.0583	0.0073	0.0745	....	....
	II.16–II.23		....	95.7	7.0%	0.0451	0.0065	0.0670	....	....
						0.2335	0.0081	0.0813	....	....
F–2	VI.4–VI.11	17.2	52.2	49.7	4.6%	0.0464	0.0072	0.1419	0.0043	0.0061
	VI.11–VI.18		49.7	49.1	1.3%	0.0243	0.0035	0.0710	....	....
						0.0042	Feces			
					5.9%	0.0749	0.0054	0.1055	....	....
F–3	VI.5–VI.12	17.2	82.4	81.0	1.7%	0.0695	0.0099	0.1212	....	....
						0.0063	Feces		0.0082	0.0143
						0.0758	0.0108	0.1322	....	....
F–4	II.10–II.17	16.7	91.1	82.6	9.3%	0.0965	0.0138	0.1559	....	....
	II.17–II.24					0.0458	0.0065	0.0793	....	....
						0.1423	0.0102	0.1171	....	....
F–5	IV.22–IV.30	16.6	57.4	56.3	1.9%	0.0415	0.0052	0.0916	....	....

TABLE II. Experiment 000.5. Feeding Raw Beef Heart.

Av. Temp.	Period	Initial or Final Wt.	Change of Wt.	Amount of Food	N. Intake	Fat Intake	Dry Feces	N. in Feces	Fat in Feces	N. in Water (Urine)	Total N. Eliminated	N. in Feces in Relation to N. Intake =100	Fat in Feces in Relation to Fat Intake =100	N. in Water in Relation to N. Intake =100
°C.		g.	%	g.	g.	g.	g.	g.	g.	g.	g.			
16.0	I.9–I.13	51.4	......	6.07	0.2057	0.1718	0.0625	0.0153	0.0328	0.1080	0.3263	2.84	7.30	52.5
17.3	I.13–I.17	......	......	9.80	0.3324	0.2778	0.0840			0.2030				61.1
17.9	I.17–I.21	......	......	9.10	0.3079	0.2572	0.0982	0.0269	0.0302	0.2085	0.4774	3.81	5.12	67.7
16.3	I.21–I.25	......	......	11.74	0.3983	0.3328	0.1568			0.2420				60.8
15.8	I.25–I.27	......	......	5.57	0.1890	0.1578	0.0792	0.0068	0.0099	0.1211	0.1279	3.60	6.21	64.1
16.8	I.27–I.29	......	......	5.73	0.1995	0.1624	0.0862	0.0085	0.0094	0.1314	0.1399	4.27	5.79	65.9
15.1	I.29–I.31	......	......	5.94	0.2015	0.1683	0.0829	0.0084	0.0097	0.1338	0.1422	4.17	5.75	66.4
16.2	I.31–II.2	......	......	5.98	0.2029	0.1693	0.0835	0.0085	0.0102	0.1423	0.1338	4.19	6.02	65.9
15.3	II.2–II.4	......	......	5.48	0.1859	0.1552	0.0692	0.0075	0.0082	0.1208	0.1283	4.03	5.22	65.0
16.4	II.4–II.6	......	......	7.43	0.2521	0.2105	0.1060	0.0105	0.0093	0.1691	0.1586	4.17	4.42	62.9
16.0	II.6–II.8	......	......	7.13	0.2409	0.2021	0.0985	0.0104	0.0061	0.1658	0.1762	4.32	3.01	68.8
15.7	II.8–II.10	91.1	......	5.37	0.1820	0.1521	0.1050	0.0106	0.0139	0.1250	0.1356	5.82	9.13	68.7
16.4	I.9–II.10	39.7	+77.3	85.34	2.8981	2.4173	1.1120	0.1134	0.1397	1.8518	1.9652	3.91	5.78	63.9
16.7	II.10–11.24	82.6	—9.33	Fasting										
17.5	II.24–II.26	82.6	......	4.48	0.1613	0.1219	0.0430	0.0048	0.0039	0.0641	0.0689	2.98	3.20	39.7
13.8	II.26–II.28	......	......	5.04	0.1814	0.1372	0.0680	0.0076	0.0061	0.1038	0.1114	4.19	4.45	57.2
15.0	II.28–III.2	......	......	4.06	0.1462	0.1105	0.0905	0.0082	0.0117	0.1551	0.1633	5.61	10.59	106.1
14.6	III.2–III.4	......	......	6.03	0.2038	0.1293	0.1210	0.0121	0.0169	0.1705	0.1826	5.94	13.07	83.2
15.4	III.4–111.6	......	......	4.40	0.1584	0.1198	0.1090	0.0107	0.0127	0.1318	0.1425	6.76	10.60	83.2
16.6	III.6–III.8	......	......	5.09	0.1832	0.1385	0.1160	0.0113	0.0109	0.1292	0.1405	6.17	7.89	70.5
15.2	III.8–III.11	95.5	......	6.54	0.2354	0.1780	0.1390	0.0113	0.0151	0.1732	0.1845	4.80	8.48	73.6
15.4	II.24–III.11	12.9	+15.7	35.64	1.2695	0.9352	0.6865	0.0660	0.0773	0.9277	0.9937	5.20	8.27	73.08

TABLE III. EXPERIMENT 000.6. FEEDING RAW BEEF HEART.

Av. Temp.	Period	Initial or Final Wt.	Change of Wt.	Amount of Food	N. Intake	Fat Intake	Dry Feces	N. in Feces	Fat in Feces	N. in Water (Urine)	Total N. Eliminated	N. in Feces in Relation to N. Intake =100	Fat in Feces in Relation to Fat Intake =100	N. in Water in Relation to N. Intake =100
°C.		g.	%	g.	g.	g.	g.	g.	g.	g.	g.			
17.1	I.19–I.27	33.6	......	4.74	0.1609	0.1344	0.0368	0.0036	0.0056	0.1344	0.1380	2.24	4.17	83.5
15.9	I.27–II.2	......	......	5.09	0.1727	0.1443	0.0540	0.0047	0.0056	0.1245	0.1292	2.72	3.88	72.1
16.2	II.2–II.8	......	......	7.23	0.2455	0.2051	0.0566	0.0050	0.0069	0.1730	0.1780	2.04	3.36	70.5
16.1	II.8–II.14	44.7	......	8.35	0.2871	0.2404	0.0864	0.0079	0.0092	0.1962	0.2041	2.75	3.41	68.4
16.3	I.19–II.14	11.1	+33.4	25.41	0.8662	0.7239	0.2338	0.0212	0.0273	0.6281	0.6493	2.45	3.77	72.5
......	II.14–II.18	......	......	Fasting										
16.3	II.18–II.23	34.8	......	2.84	0.1022	0.0782	0.0375	0.0037	0.0067	0.1074	0.1111	3.62	8.57	105.1
17.5	II.23–II.27	......	......	4.00	0.1440	0.1104	0.0763	0.0074	0.0099	0.0982	0.1056	5.14	8.97	70.0
14.8	II.27–III.3	......	......	4.72	0.1699	0.1305	0.0650	0.0066	0.0097	0.1082	0.1148	3.89	7.43	63.7
15.2	III.3–III.7	......	......	5.86	0.2110	0.1618	0.0935	0.0099	0.0139	0.1335	0.1434	4.70	8.06	63.3
15.9	III.7–III.11	46.1	......	5.53	0.1990	0.1525	0.1025	0.0102	0.0119	0.1365	0.1467	5.13	7.80	68.6
15.9	II.18–III.11	11.3	+32.8	22.95	0.8261	0.6334	0.3748	0.0378	0.0521	0.5838	0.6216	4.58	8.23	70.7

TABLE IV. EXPERIMENT 000.7. FEEDING RAW BEEF HEART.

Av. Temp.	Period	Initial or Final Wt.	Change of Wt.	Amount of Food	N. Intake	Fat Intake	Dry Feces	N. in Feces	Fat in Feces	N. in Water (Urine)	Total N. Eliminated	N. in Feces in Relation to N. Intake =100	Fat in Feces in Relation to Fat Intake =100	N. in Water in Relation to N. Intake =100
° C.		g.	%	g.	g.	g.	g.	g.	g.	g.	g.			
17.7	II.23–II.26	95.7	......	8.00	0.2880	0.2209	0.0460	0.0050	0.0355	0.1214	0.1264	1.74	16.08	42.2
14.1	II.26–III.1	......	......	3.56	0.1281	0.0983	0.1350	0.0128	0.0090	0.1168	0.1296	10.00	9.16	91.2
14.7	III.1–III.4	......	......	1.95	0.0702	0.0540	0.1280	0.0123	0.0265	0.0918	0.1041	17.52	49.1	130.8
15.9	III.4–III.7	......	......	5.40	0.1943	0.1490	0.1300	0.0113	0.0185	0.1326	0.1439	5.82	12.42	68.3
16.0	III.7–III.10	109.5	......	8.78	0.3162	0.2424	0.1920	0.0148	0.0341	0.1944	0.2092	4.68	14.07	61.5
15.7	II.23–III.10	13.8	+14.5	27.71	0.9968	0.7645	0.6310	0.0562	0.1236	0.6570	0.7132	5.64	16.16	65.9

TABLE V. Feeding Cooked Beef Heart.

No. of Experiment	Av. Temp.	Period	Initial or Final Wt.	Change of Wt.	Amount of Food	N. Intake	Fat Intake	Dry Feces	N. in Feces	Fat in Feces	N. in Water (Urine)	Total N. Eliminated	N. in Feces in Relation to N. Intake =100	Fat in Feces in Relation to Fat Intake =100	N. in Water in Relation to N. Intake =100
	° C.		g.	%	g.	g.	g.	g.	g.	g.	g.	g.			
	16.7	IV.20–IV.30	100.6	......	3.510	0.1776	0.1325	0.0330	....	....	0.1462	....	....	....	82.3
	16.3	IV.30–V.7	......	......	5.715	0.2801	0.1982	0.0620	....	....	0.1859	....	....	....	66.4
00.2	16.3	V.7–V.14	108.5	7.81	4.750	0.2404	0.1793	0.0670	....	....	0.1809	....	....	....	75.3
	15.4	V.14–V.21	......	......	5.175	0.2591	0.1875	0.0860	....	....	0.2069	....	....	....	79.9
	16.0	V.21–V.28	110.6	2.0	4.760	0.2409	0.1796	0.0554	....	....	0.1841	....	....	....	76.4
	16.1	IV.20–V.28	10.0	9.85	23.910	1.1981	0.8771	0.3034	0.0519	0.0340	0.9040	0.9559	4.33	3.88	75.5
	16.2	IV.30–V.7	60.9	......	5.37	0.2534	0.1811	0.0420	....	....	0.1682	....	....	....	66.4
	16.3	V.7–V.14	66.6	9.02	5.12	0.2359	0.1746	0.0462	....	....	0.1804	....	....	....	76.5
00.3	15.4	V.14–V.21	......	......	4.78	0.2415	0.1803	0.0874	....	....	0.1935	....	....	....	80.1
	16.0	V.21–V.28	67.4	1.2	4.96	0.2510	0.1871	0.0432	....	....	0.1839	....	....	....	73.3
	16.0	IV.30–V.28	6.5	10.66	19.29	0.9818	0.7231	0.2188	0.0401	0.0283	0.7260	0.7661	4.09	3.91	73.9
	16.2	IV.30–V.7	56.3	......	1.750	0.0886	0.0660	0.0200	....	....	0.0699	....	....	....	78.9
	16.3	V.7–V.14	......	......	4.645	0.2350	0.1753	0.0516	....	....	0.1449	....	....	....	61.7
	15.4	V.14–V.21	60.9	......	4.585	0.2316	0.1728	0.0682	....	....	0.1583	....	....	....	68.4
	16.0	V.21–V.28	62.6	......	2.380	0.1204	0.0898	0.0238	....	....	0.0999	....	....	....	82.9
	16.0	IV.3–V.28	6.3	11.21	13.36	0.6756	0.5039	0.1636	0.0265	0.0378	0.4730	0.4995	3.92	7.50	70.1
00.4	16.8	V.28–VI.1	62.6	......	3.15	0.1594	0.1188	0.0615	....	....	0.1097	....	....	....	68.9
	15.6	VI.1–VI.5	......	......	3.57	0.1806	0.1347	0.0690	....	....	0.1230	....	....	....	68.1
	17.8	VI.5–VI.9	64.8	......	3.60	0.1822	0.1358	0.0450	....	....	0.1419	....	....	....	77.9
	16.5	VI.9–VI.13	67.8	......	4.01	0.2029	0.1513	0.0475	....	....	0.1074	....	....	....	52.9
	17.4	VI.13–VI.17	69.10	......	2.73	0.1381	0.1030	0.0688	....	....	0.1359	....	....	....	98.4
	16.8	V.28–VI.17	6.5	8.31	17.06	0.8632	0.6436	0.2918	0.0763	0.0479	0.6179	0.6942	8.84	7.45	71.5
	16.4	IV.30–VI.17	12.8	22.74	30.42	1.5308	1.1475	0.4554	0.1028	0.0857	1.0909	1.1937	6.68	7.47	70.9

TABLE VI. SUMMARY.

Experiment	Duration	Nature of Food	Ratio of Dry Feces to Dry Matter of Food	Per cent of N.	Per cent of Fat	Per cent of Utilization		Average Intervals Between Feedings	Grams of Food Consumed	Increase in body wt.	Index of Growth
				In Dry Feces		Protein	Fat		per Kg. and 24 Hours		
	Days		%	%	%	%	%	Hours	g.	g.	
000.5 (a)	32	Raw beef heart	4.99	10.0	10.0	96.1	94.2	48	37.5	17.4	46.5
000.5 (b)	15	"	7.80	9.6	9.3	94.8	91.7	48	26.7	97.3	36.5
000.6 (a)	26	"	3.52	9.1	6.4	97.5	96.2	48	25.0	106.7	42.7
000.6 (b)	21	"	6.42	10.0	10.0	95.4	91.8	48	27.0	134.5	49.8
000.7	15	"	8.95	8.9	17.9	94.4	83.8	48	18.0	170.2	50.1
00.2	38	Cooked beef heart	3.4	19.1	12.7	95.7	96.1	41	6.0	2.5	41.7
00.3	28	"	3.0	20.9	14.6	95.9	96.1	34	10.78	36.3	33.7
00.4	48	"	3.7	22.6	18.8	95.7	92.5	36	10.11	42.5	42.0

TABLE VII. FEEDING RAW BEEF LIVER.

Experiment	Av. Temp.	Period	Initial and Final Wt.	Change in wt.	Amount of food	N. Intake	Glucose Intake	N. in Feces	Fat in Feces	Sugar in Feces	N. in Water (Urine)	Total N. Eliminated	N. in Feces in Relation to N. Intake=100	N in Water in Relation to N Intake=100	Sugar in Feces in Relation to Sugar Intake=100
	° C.	Days	g.	%	g.	g.	g.	g.	g.	g.	g.	g.			
02a	14	14	35.8 38.1	+ 6.4	23.58	0.2470	0.3285	0.0235	0.0540	0.0432	0.1520	0.1755	9.5	61.5	13.1
03	16	21	59.1 50.6	—14.4	84.83	0.6114	0.4100	0.1005	0.1246	0.0127	0.4413	0.5418	16.4	72.1	3,1
03a	16.5	13	49.4 50.3	+ 1.8	51.01	0.2750	0.1295	0.0420	0.0704	0.0125	0.2530	0.2950	15.3	92.0	9.7

MINNESOTA'S EXPERIMENT IN STATE FISHING.

By Carlos Avery,
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Immediately upon the entry of the United States into the war a great hue and cry arose urging relaxation of the fishing laws and regulations so as to permit the people to take fish anywhere and in any way that they chose. The pretext that the fish were greatly needed for food as substitute for meats was used as a plausible argument. This demand grew more and more insistent until it constituted a real menace to the well established conservation policy of the state.

Here is a sample expression from a banker in a country town, from a letter addressed to the Safety Commission: "Could not your Honorable Commission take up this matter with the State Game and Fish Commissioner and have the present game laws taken off for the present at least and allow us all to take whatever fish we could make use of for our own use in any way they could be caught." This is another: "I hope that you will not be influenced by a few moneyed men, but will give the settlers their rights to kill game and catch fish at any time regardless of game laws."

The Governor, the Safety Commission and the Game and Fish Commissioner were deluged with such appeals during 1917, but after the state fishing got under way they gradually subsided until now such a letter is rarely received.

The State War Board, in Minnesota known as the Public Safety Commission, which was appealed to, gave the Game and Fish Department an opportunity to make recommendations. The plan which is now in operation was recommended by the Game and Fish Commissioner as a substitute for the wide-open plan generally proposed. The Safety Commission approved by formal order, named the Game and Fish Commissioner as their agent to carry on the work according to his discretion, and appropriated $1,000.00 as his capital stock on which to commence business.

With this small beginning the enterprise started and has been self-supporting from the outset, all equipment having been purchased from the fund accumulated from the small margins on fish sales. The value of equipment and other assets at the end of the first year will approximate $25,000.00.

FISHERIES, WHERE OPERATED.

Red Lake, the largest lake in the state, is a comparatively shallow body of water some 440 square miles in area. It is nearly all included in the Red Lake Indian Reservation, abounds in certain varieties of fish and has never been fished for market. By agreement with the Department of Indian Affairs, whereby the Indians of the reservation are to receive certain benefits, arrangements were made to open up state fisheries in these waters.

The intention was, when the State fishing was first inaugurated, to confine it exclusively to Red Lake. It soon became apparent that this would result in a financial loss for several months and it was realized that in the great number of lakes of the state there were certain varieties of fish which were used but little, if at all, and there was no practical method recognized by law to take them in quantities. So we began to take tullibees with gill nets, bullheads with hoop nets and pickerel with gill nets and spears, where they were abundant and a considerable portion could be spared for this purpose.

In this way the demand for fish was met and the enterprise was made self-sustaining, while the preparation was going on for more extensive operations in Red Lake. It was not until late in May that pound nets were finally set in Red Lake, since when other state fishing has been gradually suspended as unnecessary. The fish were found to be so abundant that during May and June from two to four thousand pounds at a lift were taken from the pound nets in use.

No fishing has been done anywhere that would interfere or conflict with regularly licensed commercial fishing or tend to deplete any waters of any species, or to interfere with or injure angling. It has been the policy to take only such species as are of value chiefly as food fish and of little or no value as game fish.

The production of fish in the various localities in which operations have been carried on has aggregated as follows:

Nov. 1, 1917, to Aug. 31, 1918.

Red Lake	538,644	lbs.
Bena District, including waters of Cass, Winnibigoshish, and Leech Lakes and tributaries	281,046	"
Miscellaneous, including carp fishing in the Minnesota River	147,880	"
Mille Lac	42,808	"
Winton District, chiefly from Basswood Lake, and other International waters	39,569	"
Sandy Lake	9,681	"
Total	1,059,628	"

PRODUCTION, BY SPECIES.

Of the total production of the state fisheries for ten months ending August 31, amounting to 1,059,628 pounds, nearly one-third, or 302,333 pounds, were pike-perch or wall-eyed pike. The greater portion of these have come from Red Lake, which is heavily stocked with this species.

Next in volume came mullets or suckers, most of which were taken in April and for which there was a good demand at a low price at the beginning of the run, but which soon fell off, leaving us with a surplus difficult to dispose of.

The pike, or the variety that we call pickerel and known to the trade in our country as jacks was third in volume, most of them having been taken by Indians with spears in winter through the ice. Peculiarly, Red Lake has produced very few pickerel. If they exist there they must be small and find their way through the pound net leads, as we do not get them.

One of our staple varieties and fourth in volume, is bullheads, for which we find a lively demand the year round. We have caught these in a limited region around Lake Winnibigoshish with small hoopnets and they are marketed skinned and dressed.

What we call a "sheepshead"—known farther south as the white perch—has never been regarded as a food fish to any extent in Minnesota, but we have induced our people to eat 58,000 pounds of them; they are now regularly displayed in the best markets in the Twin Cities at 7 cents a pound.

The white fish we have caught—some 58,000 pounds—have been taken incidentally in our pound nets or by Indians with gill nets. We have not encouraged taking them. Our Red Lake white fish are light colored, range from three to five pounds in weight and are of very fine quality.

We find in Red Lake great quantities of a species known locally as "goldeyes" and which is probably one of the mooneyes. These have been used as food but little in our locality until we began to urge their use on the ground of economy. We sell them at the same price as sheepshead, lake carp and mullets, and have disposed of 51,000 pounds of them.

Next, or eighth, come the tullibees or small mongrel whitefish of which we have great numbers in Minnesota. We sell them at about the same price as pickerel. They are obtained in quantities only in the fall..

The quillback or "lake carp" is not very plentiful in our waters, but sells better than sheepshead, goldeyes or mullets. The 45,000 pounds which were taken includes a considerable proportion of Asiatic carp of which we did not keep a separate record. It might be said in passing that most of the Asiatic carp and buffalofish produced in Minnesota are taken by regularly licensed fishermen and we send nearly four million pounds a year of them to New York.

In some of our northern lakes the yellow perch is very abundant and attains a good size—often a pound or more. The 10,000 pounds of perch taken, mostly came from Mille Lac Lake and were taken when pike-perch were being caught in gill nets.

One of the most despised fish with us is the burbot or "eelpout," but we have succeeded in inducing the people to eat over 7,000 pounds of them. Our men sometimes camouflaged them "northern catfish" which seemed to help some.

The balance of our catch has been made up of rock bass, sturgeon, catfish and dogfish, or bowfin, a small quantity of each. Peculiarly, we have been disappointed in Red Lake as a producer of sturgeon. The total production of fish by varieties for the period named has been as follows:

Sixteen Varieties.

Pike Perch	302,333	lbs.
Mullets	185,242	"
Pickerel	181,757	"
Bullheads	104,089	"
Sheepshead	58,875	"
Whitefish	58,855	"
Goldeyes	51,504	"
Tullibees	48,371	"
Carp	45,256	"
Perch	10,295	"
Burbot	7,678	"
Buffalofish	2,866	"
Rock bass	2,015	"
Sturgeon	390	"
Catfish	74	"
Dogfish	28	"
Total	1,059,628	"

HOW FISH ARE HANDLED.

Our pound net fish from Red Lake are packed round, with the exception of whitefish, which are always dressed. All other fish caught by Indian or white fishermen under contract for the state are required to be furnished dressed. They are required to be delivered at certain collecting stations where they are sorted, boxed, iced, (except in winter) and shipped and billed to customers. The standard boxes, holding about 150 pounds of iced fish are used, boxes to be returned by customers and used over again several times.

HOW DISTRIBUTED AND SOLD.

At first it was necessary to sell the fish in public markets, on the streets, in department stores, or anywhere to advertise the enterprise and acquaint the people with their opportunity to get cheap fish. Almost invariably the demand greatly exceeded the supply, as the people came in large numbers and bought eagerly of the state fish.

There has in some cases been a reluctance on the part of regular retail dealers to handle the state fish on account of the margin of profit and selling prices being fixed. We have sometimes found it necessary to sell the fish on depot platforms, in barber shops, general stores, private houses, and on the streets, until a demand was created and the regular dealer recognized the desirability of handling the state fish. In public market places and city department stores people fought for preferred positions in line to get fish. Game wardens, who acted as agents, often reported selling out shipments of several boxes in short order and the demand not satisfied. Volunteer dealers in many communities are still handling the fish, sometimes with no profit whatever to themselves, purely as a patriotic service.

Wholesale dealers have in some instances shown a disposition to co-operate, in others to object and obstruct. Finally they have all come to handle and distribute most of the fish sold in Minneapolis and St. Paul on a percentage basis, the price to retailer and consumer remaining the same as if sold direct by the state. Our plan is to ship by prepaid express to all points in the state. A large part of the distribution in southern Minnesota

is satisfactorily accomplished by shipping from Red Lake to St. Paul in refrigerator carload lots and distributing from there. This insures delivery of the fish fresh and wholesome in midsummer.

The following quotation from a country newspaper describes a typical instance:

DOING HIS BIT.

"J. E. Madden, the local real estate man, has been doing a valuable service in the interest of food conservation which many people in this community are no doubt unaware of. Early last spring the State Game and Fish Commission employed help to seine fish in the big lakes in the northern part of the state, the fish to be used as a substitute for meat and sold at cost.

"The plan proved popular and has been continued ever since. Each week tons of fish are shipped to the larger cities of the state and disposed of in short order.

"The first box which came to Waseca was sent in care of Mr. Madden. He tried to get some local retailer to handle it, but none of them cared to. Mr. Madden did not propose to send the fish back so he placed the box on the walk in front of his office, dug up a scales and some wrapping paper, started a curbstone market and soon sold the fish to the people as they passed on the street.

"A box of fish arrived every week since and Mr. Madden has been right on the job as selling agent. But in this case he receives no commission or compensation for handling the fish, making change, remitting the money and other work incident to the job. Like war workers, he is doing his bit for the good of the cause. And in the meantime many a family in Waseca enjoys a fine mess of fresh fish each week at much less expense than the average cost of catching them."

It has not been practical in Minnesota to follow the admonition of the U. S. Food Administration to use the fish taken exclusively in the immediate vicinity of their production. We have found our opportunity in supplying those portions of the state which have no lakes or local fish from those other sections which abound in both. Where lakes abound, the people supply their own needs, but where there are no lakes the people have eagerly welcomed the opportunity we have given them to get fish. For some unaccountable reason there are scores of small towns in our state that never saw a fish on sale until they began to receive the state fish.

POPULARIZING COMMON FISHES.

Prior to the inauguration of the state fishing such common and lowly kinds of fishes as lake carp, sheepshead, mullets, and goldeyes (mooneyes) were seldom, if ever, seen in the better meat and fish markets of the cities and were wholly unknown in the smaller communities remote from lakes where they are produced.

By furnishing the fish in a fresh and wholesome condition and at low prices (retailing everywhere at not to exceed 7 cents a pound), and doing some advertising, we have built up a steady demand for the cheaper fishes in many places.

Little if any success has attended efforts to introduce smoked fish, nearly all our fish being bought and consumed fresh, but further efforts will be made in that direction, and the salting of certain varieties will be encouraged at times when plentiful. The U. S. Bureau of Fisheries has assisted in educational work by sending demonstrators to illustrate approved methods of smoking and curing coarse fish.

COMPARISON OF PRICES.

It has been the intention to keep the prcies as low as possible and pay for equipment needed and running expenses. It has been aimed also to maintain prices as nearly uniform as might be the year around. For instance the state has sold walleyed pike uniformly at 12 cents wholesale (retail 14 cents), while the same variety produced through regular channels has retailed at from 18 cents to 24 cents in the same markets. State whitefish have been retailed at 14 cents and 16 cents; other whitefish 22 cents to 30 cents, no better in quality. State pickerel have sold at 10 cents to 12 cents; other pickerel up to 18 cents. State bullheads retail at 14 cents dressed, others up to 18 cents. The state rough fish at 7 cents have been the only fish of the kinds in the markets.

NO INJURY TO LAKES.

By careful selection of localities for fishing and discrimination in choice of varieties taken, this great quantity of fish has been taken with little or no injury of any kind. In some cases those varieties which are used but little if at all by local people and consequently exist in abundance have been taken. In other instances a limited number of the better varieties have been taken where an abundance will permit. Some remote and little frequented lakes have been made to furnish a portion. It is apparent that Red Lake can give up a large volume of fish for a long time before any diminution will be noted, and the quality of some varieties will probably improve from year to year.

It would seem that it were safer and less apt to result in depletion, to carry on some of our commercial fishing by this method rather than by licensing commercial fishermen. More discrimination as to waters fished, varieties taken and in methods of fishing is possible, and the quantity taken at any time and place is absolutely under control. Unrestrained legal commercial fishing has all but exterminated our Lake Superior whitefish and Lake of the Woods sturgeon, and is rapidly coming to the same unfortunate result with the Lake Superior herring. There should be more state or government control of fishing with a view to conservation and our Minnesota State fishing may furnish suggestions as to more discretion and latitude in control of the industry.

BENEFIT TO THE PUBLIC.

The benefit to the people of the state and to the country has been unquestioned and apparent. Not only has a large quantity of fish at moderate prices been made constantly available, but they have been made use of, thus releasing a corresponding amount of meats and other foods for shipment and export. A distinct saving in cost has also resulted on account of the low price scale and much more fish have undoubtedly been used than would have been under ordinary conditions. The constant presence of low-priced state fish in the markets has also, without doubt, kept the prices of other fish at a lower average than would have been the case if there were no state fish to be had.

Direct evidence is not easy to get, but one instance was a letter received from a St. Paul woman expressing her appreciation of the opportunity to get cheap fish. With seven in the family and her husband employed as a janitor at $60.00 a month, rigid economy was imperative and state fish helped materially in her family to keep the larder supplied. Her case is undoubtedly typical of hundreds. Many expressions of appreciation have come from all parts of the state.

The enterprise has also served as an industry from which many settlers in remote parts of the State have added to their income. It has also served to put the business of the Indians of the Red Lake agency and elsewhere on a cash basis and has enabled them to invest liberally in Liberty Bonds and War Savings Stamps.

THE DEVELOPMENT OF MARKETS FOR NEGLECTED FISHES.

LEWIS RADCLIFFE,
United States Bureau of Fisheries.

It is a common practice in the commercial fisheries to centralize efforts on the development of means for catching and marketing increasingly larger supplies of the more highly prized fishes and to destroy or return to the water species of little or no market value. Some of the results of this practice are that the supply of some of the choice fishes has been greatly diminished, with the attendant possibility of ultimate exhaustion; predatory species of lesser value have been allowed to multiply and feed upon other more valued forms; the housewife has acquired an acquaintance with the merits of but a small number of species, and is encouraged to ask for these only, while millions of pounds of wholesome food fish are destroyed annually for lack of a market.

One of the important problems of the commercial fisheries of today is to create markets to absorb these millions of pounds of waste fish; to develop methods of preservation which will render them attractive to the consumer, and enable the fishermen to care for the surplus catch in seasons of abundance for use in periods of scarcity; to educate the public, not only to the merits of these species as food, but as to the best ways of preparing each for the table; and to provide for the utilization of the by-products. As in many fields of commercial enterprise, the waste product of yesterday has become the profit-producing product of today; so in the fisheries, the fishes which we destroy today may yield the profits of our tomorrow's work.

Upon entering this field, we should realize at the start that each species of fish, or each class, may call for special treatment; that each may present a distinct problem, varying from the simple to the very complex, and that in some cases tangible results will be attained quickly, while in others a large expenditure of time and effort will be required before the desired results are accomplished.

In some cases, the fish may possess sufficient merit and strike the popular fancy so quickly as to require only a little judicious

advertising. In other cases, the range of our activities will be much broader, but along usual commercial channels, including all phases, from the development of fishing grounds to arousing the interest of the consumer to purchase the product.

The campaign conducted by the Bureau of Fisheries to introduce the tilefish included all these phases. The summary of this work, contained in the Report of the Commissioner of Fisheries for 1916, is worthy of study here, and illustrates the effective manner in which the Federal Government can co-operate with the commercial interests in this field. "The fishing grounds were found and pointed out to the fishermen; a regular commercial fishing vessel was engaged to demonstrate the financial yield of this fishery under regular industrial conditions; the wholesale trade was enlisted in the distribution of the fish; the retailer was furnished with attractive display advertising matter, calling his customers' attention to the fact the fish was on sale; and the consumer was told about the tilefish and how to cook it, and his curiosity and interest was stimulated to the point where he wished to try it and asked his dealer for it."

The problem of creating markets for other species may prove even more intricate. In addition to the lines of development outlined above, it may be necessary to enlist the services of skilled technologists to solve problems of preparation and preservation of the fish for food, to determine by careful analysis the actual fitness for food and to develop methods of preparation of and uses for the by-products. It may even be necessary to overcome the aversion of fishermen to fishing for and bringing the fish to market, and to uproot deep-seated prejudice or actual repugnance on the part of the consumer to using them for food. We may be required to duplicate the work of the meat packing industry, of which it is said that commercial uses have been developed for every part of the hog but the squeal, and that even that is sometimes employed in phonograph records. On our ability, through extended research and a campaign of education to develop such uses and markets for all parts of these neglected fishes, may depend the margin of profit necessary to support the fishery.

As the development of fisheries and uses for sharks presents such a problem, it will serve as an illustration. In this campaign, it has been necessary to:

(1) Devise apparatus suitable for catching sharks in commercial quantities;

(2) Assemble available data as to places where and seasons of the year in which sharks can be taken commercially;

(3) Instruct the fishermen in the methods of extracting the liver oil and place them in touch with markets for it;

(4) Create markets for the hides and develop methods of removing them economically, salting and boxing them in a manner acceptable to the trade;

(5) Determine the actual fitness of the flesh of certain species for human consumption;

(6) Develop methods of stabilizing and deodorizing the liver oil with the object of using it for edible purposes, and analyze it to determine its fitness for food;

(7) Work out satisfactory methods of pickling, smoking or kippering, drying, dry-salting and canning the flesh;

(8) Conduct investigations to overcome special difficulties encountered in preserving the product;

(9) Carry on cooking experiments to determine the best methods of preparing the fresh and preserved products for the table;

(10) Overcome the objections of the fishermen to engaging in the fishery;

(11) Enlist the co-operation of the wholesale trade in distributing the fish;

(12) Aid the retailer to dispose of the fish, and furnish him with advertising matter to attract the consumers' attention.

(13) Conduct a campaign of education among the consumers to uproot their prejudices against the product and to enlist their interest in the merits of it to the point where they will buy it of their dealers;

(14) Lend encouragement to the establishment of fisheries and the installation of equipment necessary to render the by-products, that otherwise might be wasted, marketable;

(15) Encourage the conversion of waste into fish meal or scrap, and the flesh also where it is impracticable to market it for food.

As some of these individual lines of development present problems of considerable magnitude, with numerous ramifications, several of them will be discussed in greater detail.

Hides. In attempting to create markets for the hides, it was first necessary to assemble a supply of raw skins and distribute them among tanners and others desirous of ascertaining their fitness for special uses. By so doing, a large number of persons were interested to experiment with these skins.

In many cases, tanners found that their methods were unsuited to these products and some of them, therefore, assumed that good leathers could not be produced. In other cases, some success was attained, and such tanners were encouraged to continue their experiments, with the result that they have evolved satisfactory methods of tanning these hides into leathers suitable for making shoes, bags, etc., and have become interested in the development of the industry.

In the course of this work in tanning and finishing the hides, one of the principal difficulties met with was the problem of removing the shagreen, composed of minute horny denticles. Some attempted to remove this before the hides were tanned, others after tanning. The latter has been the more satisfactory.

After the hides are tanned, neutralized, dyed, rendered pliable and drained, they are given a coat of paraffin and oil, tacked and dried slowly. They are then smooth-plated and shaved on the grain side to remove the coarsest part of the grain or denticles. The hide is then gone over lightly on a rapdily revolving carborundum wheel, when it is ready for finishing. Tanners were also interested to test the hides of the different species of sharks to determine whether differences in quality exist, and the fitness of each for special uses.

Having aroused the interest of the tanners, it then became necessary to develop methods for skinning the sharks, pickling and boxing them in a manner acceptable to the trade, to supply the fishermen with this information and encourage them to save the hides. Here again difficulties arose. Unlike mammal hides, in which the flesh and hide are held together by a thin layer of connecting tissue, shark skins are firmly joined to the flesh by tough septa extending into the flesh, which have to be severed with the knife. As a result, the task of skinning sharks, particularly those of large size, was a laborious, time-consuming one, threatening to make the undertaking unprofitable. Steps have been undertaken to overcome this difficulty, and, of one device that has been

perfected, it is claimed that by its use the hide can be removed in four minutes, as compared with from one to two hours by hand.

With the accomplishment of satisfactory progress in these fields, it was necessary to make various tests as to tensile strength, wearing qualities, etc., to determine the uses to which such leathers are best suited, and to call to the attention of manufacturers of leather goods such qualities of excellence as these leathers possess, that they may be interested to purchase available supplies. As a matter of passing interest, it may be mentioned that the average tensile strength per square inch of three tanned hides was 3,479; 3,905; and 4,742 pounds respectively.

Oils. With the increased demand for and advance in price of edible oils and fats, interest has been aroused in the possibilities of rendering fish oils suitable for edible purposes. This has already been accomplished in the case of whale fat. In 1914, Denmark used 20,000 barrels of hardened whale fat in the margarin industry, and it is reported to be well suited for making margarin that keeps well and tastes well, and to be even better suited for making lard.

Processes of hydrogenation have been evolved, which, it is claimed, will render fish oil suitable for edible purposes. Our responsibility does not end here. For example, one technologist has discovered the presence of a large percentage of hydrocarbon oil in the liver oil of some sharks. In such cases, the oil may be unsuitable for food purposes. It is important that information of this character be ascertained and made available.

As hydrogenation is usually accomplished by the use of a metal catalyist such as nickel, presence of traces of which may render the oil unsuitable for food, it is important that care be exercised to avoid this contingency, or methods developed which do not require the use of such metals. In addition, hydrogenation should not be carried so far as to raise the melting point of the fats above 98.6° F., the temperature of the body, as otherwise they are not liquefied in the body.

Preservation. In developing satisfactory methods of preserving the flesh, difficulties have been encountered, some of which may require extended research and experiment before they are overcome. For example, the flesh contains small quantities of urea, a substance of itself practically harmless. By various methods, the urea may be converted into ammonia, which in

itself is harmless, but, on account of its odor, gives the impression that the product is spoiled, unfit for food. We have learned by experiment that in pickle the urea slowly dissolves out, uniting with the salt in the brine, thus tending to eradicate this objectionable feature. Little or no trouble has been experienced with the flesh which has been pickled and smoked or kippered, and the canned, kippered fish is very attractive indeed.

To some, it may appear that the writer has wandered afield in this discussion, has laid undue stress on the difficulties which have to be met. This has been done purposely, with the hope of bringing about a more complete appreciation of the varied character of the problems and the way in which they may be met.

It is to be feared that some may be discouraged by the magnitude of the task which confronts them in developing markets for these neglected fishes. However, by concerted effort on the part of those engaged in the fisheries, state and federal agencies and skilled technological investigators, it can be done. In fact, much has already been accomplished. By way of illustration, it is estimated that on the basis of the weight of the fresh fish, the following quantities of certain of these neglected fishes were marketed during 1917: burbot, 500,000 pounds; grayfish, 4,000,000 pounds; sablefish, 4,000,000 pounds; Alaska Scotch-cured herring, 2,000,000 pounds; tilefish, 6,000,000 pounds; and whiting, 20,000,000 pounds. As yet, no estimates are available as to the results of the campaign in introducing drumfish, eulachon, menhaden, sharks, fish roe and buckroe, etc. The markets absorbed these 35 millions or more pounds of fish in a single year and will absorb increasingly larger quantities. For every time that we create a place in the market for one of these new fishes, we weaken the consumers' objections to trying new fishes.

Is not this question of marketing the neglected fishes one of the big problems of the commercial fisheries of today, and is it not worthy of our concerted effort to continue the development of such fisheries, observing proper safeguards to prevent depletion, until we have no more waste than in other highly organized industries? My answer is in the affirmative.

PRODUCTS OF THE COMMERCIAL FISHERIES OF THE UNITED STATES.

By John N. Cobb.

The heavy drain upon the ordinary food resources of the world, as a result of the devastation wrought throughout the countries of Europe by the warring armies, and the reduction in producing power through this and the drafting of the erstwhile tillers of the soil into these fighting armies, has focused attention upon the denizens of the fresh and salt waters of the world as a source from whence the shortage caused by the above factors may be partly, if not wholly, met. The U. S. Bureau of Fisheries, ably seconded by various state fish commissions, and public and private organizations, firms and individuals, has done excellent work in creating new and extending old markets for fishery products, and also in creating a demand for hitherto neglected aquatic products.

Owing to its extremely favorable situation, with the Atlantic on its eastern and southeastern side, the Pacific on the west and the Great Lakes on the north, with its interior covered with a network of rivers, some of them amongst the largest in the world, while thousands upon thousands of big and little lakes dot the country, the commercial fisheries of the United States have been extremely important and valuable from early times. For a number of years they have surpassed those of any other country in both extent and value, and this superiority has been more than maintained since the great drive upon the fisheries began three years ago.

As a result of the lack of a central body collecting annual statistics of our fisheries (Congress has never provided the U. S. Bureau of Fisheries with sufficient money and personnel to make possible a thorough statistical canvass of all our fisheries each year), it is not an easy matter to arrive at the proper quantity and value of the same. Where available, and of sufficiently late date, data collected by the U. S. Bureau of Fisheries have been used. A few states collect fairly accurate statistical data annually and these have been used in such cases, while by correspondence and in various other ways the author has collected much valuable data

which have been incorporated in the table shown herewith. Great conservatism has been used in collecting and handling the data, with the result that it undoubtedly understates rather than overstates the actual production.

No account has been taken of the enormous quantity, in the aggregate, of fishery products caught and consumed annually by sportsmen and semi-professional fishermen. In Alaska, it is estimated, on very reliable information, that the natives alone catch and consume some 30,000,000 pounds of fish, none of which appears in the above table, and the same is true to a much less extent in a number of other states.

The table below shows the production by states under three headings. "Fishes proper" include all those used for food. "Other edible products" include the meats of mollusks, crustaceans, etc., while "Non-edible products" comprise fishes (such as menhaden) used solely for fertilizer and oil, shells, skins of aquatic animals, kelp, seaweed, etc., The products are shown just as landed by the fishermen, and the value is that received by him for the same. Large quantities of products landed are either canned, salted, mild-cured, smoked, or otherwise prepared, which work gives employment to many thousands of persons, and consumes millions of dollars' worth of tinplate, box shooks, barrels, salt, oil, and the thousand and one things needed in the preparation of secondary products, all these vastly increasing the value of the goods. In 1917 the canned salmon produced in Alaska alone sold for about $45,000,000, but in the table only the value of the raw fish has been shown.

PRODUCTS, BY STATES, OF THE COMMERCIAL FISHERIES OF THE UNITED STATES.

States	Fishes		Other Edible Products		Non-Edible Products		Total Products*		Total Products in 1908†	
	Pounds	Value	Pounds	Value	Pounds	Value	Pounds	Value	Pounds	Value
Alabama	7,178,700	$ 269,600	3,359,819	$ 79,484			10,538,519	$ 349,084	10,665,000	$ 387,000
Alaska	460,301,646	7,770,532	97,319	7,186	8,395,664	$ 635,995	468,794,629	8,413,713	229,194,603	3,300,751
Arizona	80,000	6,400					80,000	6,400		
Arkansas	4,475,100	133,200	33,000	4,100	8,060,050	70,100	12,568,150	207,400	12,567,000	207,000
California	178,450,472	5,353,514	23,757,782	2,138,190	797,812,174	205,894	1,000,020,428	7,697,598	47,477,000	1,970,000
Colorado	1,360,166	185,493					1,360,166	185,493		
Connecticut	65,055,070	593,837	29,201,635	2,048,761	95,592,810	389,419	189,849,515	3,032,017	66,942,000	2,982,000
Delaware	5,278,200	208,100	3,759,996	243,617	66,854,830	274,476	75,893,026	726,193	70,769,000	541,000
Florida	61,548,640	2,361,093	14,621,629	422,580	4,330,444	636,416	80,500,713	3,420,089	74,087,000	3,389,000
Georgia	4,505,800	344,000	7,993,579	275,683	700	3,600	12,500,079	623,283	14,828,000	701,000
Idaho	1,640,000	220,000					1,640,000	220,000		
Illinois	40,363,454	1,280,187			14,926,000	338,398	55,289,454	1,618,585	74,620,000	1,436,000
Indiana	1,076,900	67,950			18,488,000	251,343	19,564,900	319,293	15,507,000	223,000
Iowa	5,222,493	228,089	95,500	2,900	4,700,500	45,600	10,018,493	276,589	8,867,000	215,000
Kansas	432,000	28,000			157,000	2,356	589,000	30,356	432,000	28,000
Kentucky	1,975,100	90,100	1,900	90	3,413,000	18,000	5,390,000	108,190	5,390,000	110,000
Louisiana	11,093,400	428,800	50,382,700	1,322,178	350,500	126,700	61,826,600	1,877,678	46,160,000	1,569,000
Maine	263,231,482	4,892,686	39,314,587	2,847,541	44,910	2,420	302,590,979	7,742,647	173,843,000	3,257,000
Maryland	65,057,784	724,118	58,974,535	2,468,715	15,621,911	105,058	139,654,230	3,297,891	113,796,000	3,306,000
Massachusetts	201,973,031	6,434,259	10,018,190	1,210,697	4,239,000	347,800	216,230,221	7,992,756	244,313,000	7,095,000
Michigan	29,251,327	1,469,615			923,000	26,613	30,174,327	1,496,228	38,302,000	1,473,000
Minnesota	32,601,679	1,394,147	687,500	275,000	2,144,000	53,115	35,433,179	1,722,262	7,475,000	192,000
Mississippi	8,520,600	163,500	14,075,340	325,502			22,595,940	489,002	20,547,000	556,000
Missouri	6,478,900	242,800	91,900	11,500	212,200	18,230	6,783,000	272,530	6,751,000	271,000
Montana	110,000	6,000					110,000	6,000		
Nebraska	399,000	22,000			55,000	610	454,000	22,610	399,000	22,000
Nevada	107,536	12,834					107,536	12,834		
New Hampshire	642,000	51,600	336,710	109,960			978,710	161,560	677,000	53,000
New Jersey	51,663,426	1,497,592	19,748,819	1,298,770	22,277,610	62,644	93,689,855	2,859,006	74,827,000	3,069,000
New Mexico	70,000	4,900					70,000	4,900		
New York	14,872,296	1,605,560	39,173,444	3,879,281	95,221,710	352,619	149,267,450	5,837,460	76,485,000	4,594,000
North Carolina	38,283,700	1,731,900	4,880,144	279,428	47,593,110	125,300	90,756,954	2,136,628	101,422,000	1,776,000
North Dakota	100,000	7,000					100,000	7,000		
Ohio	31,016,159	1,614,478			50,000	1,236	31,066,159	1,615,714	28,917,000	840,000
Oklahoma	86,700	4,300					86,700	4,300	6,700	300
Oregon	35,207,424	1,518,326	700,199	49,268			35,907,623	1,567,594	28,217,000	1,356,000
Pennsylvania	13,147,367	582,100	738,878	56,225			13,886,245	638,325	11,888,000	513,000
Rhode Island	34,767,000	695,100	18,191,002	1,656,961			52,958,002	2,352,061	44,254,000	1,752,000
South Carolina	2,988,600	140,200	5,152,768	106,677	100	75	8,141,468	246,952	14,104,000	288,000
South Dakota	70,000	4,200			260,000	4,198	330,000	8,398	70,000	4,200
Tennessee	2,329,300	97,200	6,700	1,200			2,336,000	98,400	4,506,000	112,000
Texas	8,864,671	380,453	2,601,999	156,888	7,070	1,450	11,473,740	538,791	10,439,000	446,000
Utah	1,481,863	67,458					1,481,863	67,458		
Vermont	678,682	45,069					678,682	45,069		
Virginia	128,102,295	1,333,342	75,551,968	3,334,991	291,305,099	1,012,682	494,959,362	5,681,015	312,515,000	4,716,000
Washington	145,303,549	5,970,679	3,426,439	541,384	4,383,125	141,632	153,113,113	6,653,695	100,456,000	3,513,000
West Virginia	33,000	2,000					33,000	2,000	33,000	2,000
Wisconsin	24,691,448	871,015	438,181	9,212	6,304,000	153,672	31,433,629	1,033,899	30,953,000	1,067,000
Wyoming	230,000	13,800					230,000	13,800		
Hawaii	6,556,217	635,366	416,518	42,531			6,972,735	677,897	6,972,735	677,897
Total	1,998,954,177	53,604,492	427,830,680	25,206,500	1,513,723,517	5,407,651	3,940,508,374	84,418,643	2,129,621,338	58,009,648

* Made up from data for the latest periods available.

† With the exception of Alaska and Hawaii this data is from the published results of the combined U. S. Census and Fisheries Bureaus investigations for the year 1908.

PER CAPITA CONSUMPTION.

Much interest has been exhibited in the per capita consumption of fish in the United States. We are heavy importers and exporters of fishery products. During the fiscal year ended June 30, 1917, we imported 320,876,663 pounds, valued at $22,635,983, while during the same period we exported 183,355,571 pounds of domestic products, valued at $19,875,614, and 6,529,627 pounds of foreign products, valued at $655,034, a total of 189,885,198 pounds exported, valued at $20,530,648, leaving the net quantity of imports over exports at 130,991,465 pounds and $2,105,335. The total production of edible products in our commercial fisheries amount to 2,426,784,857 pounds, to which should be added 130,991,465 pounds, representing the net imports, making a total of 2,557,776,322 pounds consumed in this country. Estimating the population of the United States (including Alaska and Hawaii) at 100,000,000, this would show a consumption of 25.57 pounds each year by every man, woman and child.